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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT
7 RUE ANCELLE, 92200 NEUILLY-SUR-SEINE, FRANCE

AGARD CONFERENCE PROCEEDINGS 553

The Clinical Basis for Aeromedical Decision Making

(Les bases cliniques pour la prise de décision dans le domaine aéromédical)

Papers presented at the Aerospace Medical Panel Symposium held in Palma de Mallorca, Spain in April 1994.

NORTH ATLANTIC TREATY ORGANIZATION

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According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

— Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;

— Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);

— Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

— Improving the co-operation among member nations in aerospace research and development;

— Exchange of scientific and technical information;

— Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

— Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

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Preface

This symposium addressed a topic of ever-increasing importance -- the rationales behind aeromedical decisions. Lack of available data required past decision-makers to be conservative when deciding who should fly and who should not. Papers in this symposium updated available data and provided a focal point for discussion and re-evaluation of aeromedical selection and retention standards. Three discussion periods allowed for open exchange on topics of particular concern to member nations i.e. cardiovascular and neurological problems and HIV.

Préface

Cette conférence concernait un sujet d'importance toujours grandissante — les bases concrètes de la prise de décision sur l'aptitude médicale en aéronautique. Le manque de données disponibles nécessitait dans le passé que les responsables soient prudents dans leur prise de décision concernant l'aptitude au vol. Les articles de cette conférence mettaient à jour les données disponibles et fournissaient un point de départ à la discussion et à la réévaluation des standards médicaux de sélection et de révision de l'aptitude dans le domaine aéronautique. Trois périodes de discussion ont permis des échanges sur des sujets d'un intérêt particulier pour les nations membres comme les problèmes cardio-vasculaires, neurologiques et le SIDA.

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by

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1. SYMPOSIUM

THE CLINICAL BASIS FOR AEROMEDICAL DECISION-MAKING 18-21 APRIL 1994, Palma de Mallorca, Spain.

2. INTRODUCTION

Authors from eleven countries presented thirty papers in this four day meeting which included a technical tour. Significant to this meeting was the attendance and presentation of a paper by a representative of the Czech Republic. Also of significance, was a clinical topic, the first since October 1991.

3. THEME

This symposium addressed a topic of ever-increasing importance - the rationale behind aeromedical decisions. Lack of available data required past decision- makers to be conservative when deciding who should fly and who should not. Papers in this symposium updated available data and provided a focal point for discussion and re-evaluation of aeromedical selection and retention standards. Three discussion periods allowed for open exchange on topics of particular concern to member nations i.e. cardiovascular and neurological problems and HIV.

4. PURPOSE AND SCOPE

The purpose of this symposium was to exchange data, experience, and management rationales dealing with the very difficult task of aero-medical decision-making. Sharing this information would enable nations to update management protocols based upon experience and data made more powerful by its collective nature. Such exchange would also eliminate costly redundant research and help focus future research and collaborative efforts with the purpose of more effectively using AGARD member nation resources and solving the more difficult or most frequently encountered problems.

The scope of this symposium was broad, being determined not only by the topics of the papers, but also, because of the open discussion periods, by the attendees and member nations needs and interests. Of particular interest are cardi-ovascular and neurological problems including cardiac dysrhythmias, head injuries, and human immunodeficiency virus since these are either responsible for the greatest number of problem decisions or the most difficult. The mechanisms for granting waivers was an additional area of interest.

5. SYMPOSIUM PROGRAM

The symposium comprised five sessions each dealing with an aspect of the decision-making process in clinical aerospace medicine. Topics did not deal with clinical conditions alone but also with the mechanisms to ensure consistency and necessary follow-up.

The symposium key note address speaker was Richard Hickman M.D. M.P.H., Consultant in Internal and Aerospace Medicine at the Mayo Clinic in Rochester, Minnesota and formerly Chief, Clinical Science Division at the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas U.S.A.

Session I dealt with the overriding principles behind aeromedical

standards, the mechanisms used by member nations, and the collective experiences of these waiver systems. Included was a discussion period entitled "Should This Pilot Fly?"

Session II addressed the process of evaluating aircrew members who are being considered for waiver for selected conditions.

Session III considered the difficult area of decision-making when neurological conditions are involved. Since conditions under consideration have the potential to cause sudden incapacitation, participant interest was particularly keen during the discussion period.

Session IV presented new information on a number of conditions involving multiple systems. Of particular note was the recommendations from study groups based on over two decades of data.

Lastly, Session V featured a paper from the Czech Republic and a final discussion period.

6. TECHNICAL EVALUATION

The topics addressed in the thirty papers presented in this symposium served to both increase our knowledge of the current available experience with diseases of aeromedical significance and to underline the areas where data is sparce and decisions are necessarily on less firm ground. The papers covered management and decision-making systems, specific protocols for arriving at the decision-making point, data collected over years of research which can assist in decision-making, challenges presented by specific conditions, and discussion of possible future collaborative efforts aimed at putting decision making for particularly vexing conditions on a firmer scientific basis in the least time for the least commitment of resource for any particular country.

The keynote address was just that. It characterized the setting of aeromedical decision-making as one in which our understanding of the true nature of asymptomatic diseases and disorders is both rudimentary and simplistic. A setting in which our very physical standards are an open declaration of our ignorance, for why else would we be required to make the same decision in the same way, every time instead of individualizing dispositions as done in clinical medicine? The speaker both lamented and endorsed this systematic, even rigid, process for arriving at dispositions, acknowledging that it is indispensable for aircrew standards research.

Dr. Hickman clearly differentiated the practice of clinical medicine from that of aerospace medicine, where by almost any standard, clinical practice is conducting upon a much more robust foundation than aerospace. He accepted that some of this is inherent and unalterable, however he further noted that there are aspects of aerospace medicine which are amenable to alteration. By addressing particular information voids we can facilitate sound aeromedical decisions. These areas are: the natural history studies of asymptomatic disorders, the merging of medical epidemiologic data on subclinical processes in air crew. Dr. Hickman further focused our attention on selection research -- research tied to outcomes of interest -- as offering the greatest return on investment.

Having identified the milieu in which we practice our specialty, and suggested areas where we can make significant progress for the least investment, Dr. Hickman challenged the Aeromedical Panel of AGARD to serve as the sponsor for true multinational research projects. Both the enormous pools of talent and the clinical denominator to produce solutions are available to the AMP. The area of pharmacology is particularly conducive to this

collaborative approach since each NATO member has areas of excellence which they could contribute. Having decided on which drugs were of interest to the AGARD community, member nations would then work in parallel to produce rapid results with great economy. This information would benefit both the enormously to the international aeromedical knowledge base. This approach would allow nations to have more therapeutic agents available to them to treat disorders of aircrew while maintaining them on flying status, thus saving enormous sums on training and repacement costs.

The formal program began, quite naturally, with the processes involved in allowing an aviator with a disqualifying medical condition to obtain a waiver to fly. Paper #1 (Giovanetti) clearly spelled out the criteria necessary to consider and aviator for waiver:

a. There must be minimal risk of sudden incapacitation.

b. There must be minimal potential for subtle performance decrement, particularly with regard to the higher senses.

c. The condition must have resolved or be stable and be expected to remain so under the stresses of the aviation environment.

d. If there is a risk of progression or recurrence, the symptoms must be easily detectable and must not pose a risk to the safety of the individual or others.

e. The condition must not require exotic tests, regular invasive procedures or frequent absenses to monitor for stability or progression.

f. The condition must be compatible with performance of sustained flying operations in austere environments worldwide.

Two examples of printed guidelines for requesting waivers were distributed to attendees by the US Air Force and Navy.

Most waiver systems, as noted in papers #2 (Vastesaeger), #3 (Bailey), #4 (Gallagher), #5 (Rios-Tejada) are highly centralized yet attempt to individualize the categories (paper #1) and consider of factors such as experience, aircraft type, mission, and medical condition. A review of waiver data (paper #2,3,4, and 5) was particularly helpful in identifying those conditions most likely to cause disqualification, most likely to be waived, and most frequently seen. This data was consistent for the three nations presenting. Such data systems, particularly the extensive Aviation Medical Data Retrieval System (AMDRS, paper #6 Nickle), offer much as a resource for epidemiologic studies. However, the point was made in the very active discussion period, that the most valuable information these data systems can give the aeromedical community is prospective studies addressing such questions as: How long was the waivered aviator's flying career? Was he ultimately disqualified for this condition? and most importantly, Was he involved in any mishaps and was his condition casual or related?

The next topic for consideration of the symposium was the evaluation of the aviator, whether screening for disease or determining the aeromedical significance of discovered abnormalities. Paper #8 (Reichenbach-Klinke) outlined the attributes of an effective aviation medical screening test as one: designed to detect conditions which are a threat to flying safety, with high sensitivity and specificity, and inexpensive to run. We have not always been successful in achieving these characteristics and many screening systems have come into general use which were of questionable value (paper #16 DeVoll). Although this is understandable

given the critical need for tools to assist the decisionmaker, we must subject every screening test to rigorous epidemiologic scrutiny in order to ensure it is fulfilling its intended purpose.

Paper #16 demonstrated a rigorous review which resulted in a recommendation to abandon a test for the evaluation of syncope and to rely on a step-wise algorithmic approach, which is highly individualized and, as always with syncope, very dependent on history. Paper #14 (Merchant) described, on the other hand, a method of evaluating psychologic fitness in the aviator or potential aviator which appears to offer a consistent, simple tool. However this system, as with many used in selection, has not been rigorously examined because of the requirement for long term prospective studies, and the follow-up of non-selectees. Paper #15 (Bles) described a less expensive, highly sensitive and specific test to detect susceptibility to motion sickness, and demonstrates what should be the goal of test designers in aviation medicine. Paper #9 (Danese) advocated thyroid stimulating hormone as a screen for thyroid disease but demonstrated another important principle of screening in recommending that the test be used for those at risk for developing hypothyroidism rather than the entire screened population. Paper #10 (Seigneuric), and #12 (Ossard) presented excellent use of technology to functionally evaluate, in a more practical manner, an aviator with a demonstrated medical condition: the in-flight Holter, and the medically monitored centrifuge ride. Lastly, paper #13 (Myhre) challenged the time honored system of putting aviators involved in mishaps immediately back into the cockpit, and offered compelling reasons why this should be done only after adequate counseling.

Since neurologic conditions are particularly likely to result in subtle or catastrophic incapacitation, they are of great interest to the aeromedical decisionmaker. Yet decision criteria are still primitive. Paper #18 (Porcu) addressed that challenging area of mild head injury and concluded that there exists no diagnostic protocol with an unequivocal prognostic value and therefore we must use electrophysiologic, neurophysiologic and neuropschologic tests available. However these tests would be of much more value, the authors contend, if baseline tests were available for comparison. Paper #19 (Glaser) and #20 (Ribeiro) also advocated the use of electrophysiologic, particularly the EEG, in the selection of aircrew, however paper #21 (Firth) challenged its value: "Because and abnormal EEG has meant de-selection and most rejected candidates have not been followed up, the sensitivity and specificity of the EEG in the screening setting has yet to be established." He emphasized the past and family history as the significant criteria since first seizures in the ages group 20-60 are due to alcohol, head injury, infection or tumor, for which no EEG markers would be present at selection.

Paper #22 (Rios), #23 (Pippig), and #24 (Feud), dealt with the management of spine and spinal nerve injury which calls for examination, radiographic studies, and electrophysiologic tests to fully evaluate the condition. Rios goes further too recommend that baseline MRIs be obtained to offer a baseline for comparison with a post ejection spine, or a post long term high G exposure. This, of course, would be valuable information, however it challenges the cost effective criteria for a good test.

Lastly, paper #28 (Azofra) reviewed the challenge to decisionmakers posed by human immunodeficiency virus (HIV). The paper accentuated the need for studies which evaluate asymptomatic seropositive individuals in order to assist in determining

the disposition of these difficult cases. There was much discussion on this topic and most agreed that until more information is available, HIV positive aviators must be evaluated on a case by case basis.

The next session dealt with a variety of conditions. Paper #25 (Richardson) and #26 (Munson) demonstrated the "gold standard" of aeromedical studies and the approach which is an absolute requirement for the aeromedical decisionmaker. These papers reported the results of two long term prospective studies dealing with supraventricular condition to the flight surgeon, and sarcoidosis. With the power of a cohort study with hundreds of person follow-up years, these studies were able to recommend significant liberalization of the present standards. Unquestionably, these types of studies represent the solution to many of the problems facing the aeromedical decisionmaker today, including many of the topics discussed at this symposium.

Paper #27 (Saboe) offered another alternative to the prospective study approach of papers #26 and #27. By means of a retrospective approach combined with an extensive review of recent literature, a practical disposition for aviators with asymptomatic cholelithiasis was proposed, once again, significantly liberalizing former approaches.

Paper #29 and #30 (Ivan) offered comprehensive reviews of two important ophthalmolgic topics, color vision and photo-refractive keratectomy (PRK). Ivan presented a thorough review of color vision standards, and clearly demonstrated the increased demand on color vision capabilities of the modern aviator. Given these demands, it is clear we must select for the "super cone man" the aviator whose color vision will be able to capitalize on the aircraft displays and other color challenges in the aviation (to include assessment of blue/yellow performance) and frequent testing combined with new standards. PRK is surgery using laser technology to ablate and reconstruct the cornea with the intent of changing refraction. As with radial keratotomy (RK) this procedure is attractive to aviation candidates who might otherwise be disqualified for flying. Although it appears, Ivan contends, that PRK is most likely going to be widely accepted and a successful way to treat myopia, he feels it has no place in the aviation environment until fully investigated to include the long term effects of the procedure.

The last paper #31 (Rada) offered a revealing review of an eleven year study to determine the use and effectiveness of selected medications in Czech aviators with medical conditions which would have otherwise been disqualifying. The paper is the first by a former Warsaw Pact nation at an AMP symposium and opens a new era of aeromedical cooperation.

7. CONCLUSIONS

7.1 Aeromedical decisionmakers face significant pressures in a resource limited environment to maintain trained aviators in the cockpit, and select candidates who will fly a full career.

7.2 New medical conditions such as HIV, and new technology such as photo-refractive keratectomy present new challenges to the decisionmaking process.

7.3 Well designed studies with large denominators can provide the data necessary to make effective aeromedical decisions.

7.4 Reduced resources limit our abilities to accomplish the necessary studies.

7.5 The free exchange of aeromedical experience amongst nations offers the opportunity to obtain the data

necessary to make difficult aeromedical decisions.

8. RECOMMENDATIONS

8.1 The Aeromedical Panel of AGARD continue to sponsor clinical symposia designed to share acquired data in order to assist member nations in making difficult aeromedical decisions.

8.2 The AMP act as a focal point for developing joint studies which can provide the necessary study subjects and expertise not possible in any one member nation.

8.3 The AMP propose a AGARD working group to develop the mechanism for joint evaluation of medications for potential aviation use.

THE CLINICAL BASIS FOR AEROMEDICAL DECISION MAKING

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Mr. Chairman, AGARD colleagues, and guests. Please accept my gratitude for your kind invitation to open this symposium. It is good to see you again. My qualifications to open this symposium do not, in my opinion, derive from my clinical credentials, nor from my 25 years of experience in clinical aerospace medicine. My singular qualification to address you is built upon my belated understanding of how very ignorant I am of the true knowledge base upon which aeromedical decisions must be based. Our understanding of the true nature of asymptomatic diseases and disorders is so very rudimentary and simplistic when compared to the way things really are. I could not have given this keynote address 10 years ago, nor even five years ago. I can now at least attempt this task since I believe that I now understand the subject, because I am acutely aware of my ignorance. Please allow me to quote John Ruskin (1819-1900): "To know anything well involves a profound sense of ignorance."

Perhaps one needs a 40-year career in aerospace medicine, with the first 20 years culminating in a sense of what is not known, gradually absorbing the impact of new medical technology, striving to cope with the demands of new aerospace weapon systems, learning that there is no substitute for natural history and epidemiological studies in aircrew, and also learning that there is no alternative to physiologic experiments upon which all medicine, including aerospace medicine, is based. One could then spend the following 20 years applying these concepts to aircrew standards research.

This is the first AGARD paper which I have given which did not require data. I do not choose to tell you the current state of waiver policy for a host of abnormalities. I do wish to share some philosophy with you.

We are all accustomed to the fact that in aerospace medicine we must have physical standards--and because we have such standards, we are occasionally accused of hiding our ignorance behind the rules and regulations. Exactly the opposite is true. The physical standards are an open declaration of our collective ignorance, which requires us to make the same decision in the same way, every time. How else will we eventually learn the answers, if we have no systematic approach which we can continually audit? We cannot defer our decisions. Even when a solid factual basis for a decision is absent, we often find ourselves in a situation described by Immanuel Kant (1724-1804): "It is often necessary to make a decision based upon information which is sufficient for action, but not sufficient to satisfy the intellect". It seems quite appropriate to begin a discussion of clinical decision making in aerospace medicine with a reference to Kant. Kant held that the content of knowledge comes a posteriori from a sense of perception, and the form of knowledge is determined by a priori categories of the mind. In clinical aerospace medicine, we are often dealing strictly from a perceptual standpoint. In many ways, our outlook is still Kantian, but the most desirable goal for aerospace medicine is to evolve along the more analytical lines of Jung or the systematic mathematical philosophy of Pascal. While we must often act under nebulous circumstances, we must never pretend to a wisdom which does not exist. Aircrew physical standards must be viewed as a system which we continually audit for outcome, modify with new physiologic data, and define new subsets as new diagnostic tools evolve.

We are largely faced with three situations in clinical aerospace medicine. (Table No. 1)

Presented at a Symposium on 'The Clinical Basis for Aeromedical Decision Making', April 1994.

Table No. 1 CLINICAL DECISIONS IN AEROSPACE MEDICINE

1. The aviator with overt clinical symptoms
2. The aviator with documented asymptomatic disease
3. The asymptomatic aviator with abnormal tests only

The disposition of overt, symptomatic disease is not especially difficult, nor is it the most common of the decision types before us. The aviator with documented, but asymptomatic disease, requires a decision based upon the natural history of the subclinical disorder and upon the pathophysiologic effects of the disorder in the aerospace environment. Historically, we have made conservative, safe, and expensive decisions, trapped in our ignorance of the subclinical disorder. The most difficult case is the one most commonly encountered in aerospace medicine--an aircrew member with abnormal tests, often requiring additional extensive testing to elucidate the screening tests. Case #1 is the common clinical case of everyday contemporary medical practice. Cases #2 and #3 are largely confined to occupational and aerospace medicine.

Most of us have learned clinical decision making in the sick patient environment. But, clinical decision making in aerospace medicine is more than superficially different from traditional clinical decision making. If we are to improve clinical decision making in aerospace medicine, perhaps it would be helpful to contrast aerospace medical decision making with usual clinical practice, paying special attention to those areas of aerospace medicine decision making which can be enhanced. (Table No. 2)

Table No. 2 COMPARISON OF CLINICAL AND AEROSPACE MEDICINE DECISION MAKING

	Aerospace Medicine	Clinical Medicine
Clinical State	Usually no symptoms	Usually symptomatic
Natural History Data	Sparse	Usually available
Prevalence of Suspected Disorder	Low	Moderately high or high
Predictive Value of Diagnostic Tests	Low for positive tests. Usually high for negative tests.	High for positive tests. Moderately high for negative tests.
Diseases Subsets Defined	Usually very few	Many subsets, extensive nomenclature
Outcome Data	Sparse	Usually abundant
Decision Goals	Prove safe to fly, delabel patients	Diagnose and treat
Decision End Point	Fly or not fly	Treat or not treat
Requirement to make a Decision	Always, usually with some urgency	Observation, deferred decisions common
Impact of the Decision	Potentially profound	Usually no penalty for empiricism, trial and error
Surveillance and Retesting	Frequent and extensive	Dictated by clinical constellation, often minimal
Physiological Basis of Decisions	Multiple information voids	Well established
Pharmacological Data	Often little data for the aviation environment	Voluminous data, multiple trials
Number of Decision Makers	Many	One or few
Economic, Life Circumstances Impact on the Patient	Potentially of great magnitude	Often great, but often minimal for same disease in a nonaviator
Desires and Wishes of the Patient	Often cannot be considered	Wide range of options open to the patient

The clinical state is the first and most obvious difference. Clinical medicine is usually practiced upon a large natural history data base, but such data bases in aerospace medicine for asymptomatic disorders are quite sparse. Because we are dealing with a healthy population in aerospace medicine, the prevalence of suspected disorders is low, which has a profound effect upon the predictive value of diagnostic tests in the asymptomatic population. In the aircrew population, predictive values are usually quite high for negative tests, but conversely quite low for positive tests. Positive predictive values are usually quite high in a symptomatic population, where the suspected disease is usually quite prevalent. Negative predictive values are usually moderately high, but not as high as in a well patient population. Almost every diagnostic category in clinical medicine has multiple subsets and extensive nomenclature. The diagnostic subsets in aerospace medicine are usually not well described. Many diagnostic subsets in clinical medicine are based upon the symptomatic state, mode of presentation, and rate of progression of the underlying disease. These markers are absent in the asymptomatic subject. Usually, there are abundant outcome data for the common symptomatic diseases. Outcome data for asymptomatic disorders in aircrew continues to be sparse. The goal in clinical medicine is to diagnose and treat. The goal in clinical aerospace medicine is to prove the aircrew member safe to fly, often requiring us to spend extensive resources to delabel aircrew members whose diagnostic testing is consistent with a disease process. In general, the endpoint in aerospace medicine is to fly or not fly. The endpoint in clinical medicine is to treat or not treat. In clinical medicine, especially in the patient who is not acutely ill, we frequently have the luxury of making repeated observations, and often deferring diagnostic decisions until the disease process has fully declared itself. In aerospace medicine, we are virtually always required to make a decision, usually with some urgency. In the clinical patient who is not acutely ill, there is usually no penalty for empiricism, trial and error, and diagnostic conservatism. In clinical medicine, we are rarely placed in an "all or none" situation early in the course of the disease. Because of the implications of mission readiness, flying safety, and impact on the aircrew member's career, clinical decisions in aerospace medicine have immediate and substantial impact. Surveillance and retesting in clinical medicine are dictated by the clinical constellation. Surveillance and retesting of both healthy aircrew members and those with waivered disorders is frequent, extensive, and expensive. The physiological basis of clinical decisions is usually well understood, while multiple information voids in the area of physiology continue to exist in the aerospace environment, especially in the area of high performance flying. In clinical medicine, a wide variety of pharmacological therapies are available, based upon voluminous data and multiple clinical trials. In aerosapce medicine, the available choice of drugs is quite constricted, and few drugs have been rigorously tested for the aviation environment. In the sick patient environment, clinical decisions are made by one physician, or a very few physicians. In aerospace medicine, a far larger number of clinicians, administrators, and review authorities are involved in the decision making process. Purely clinical decisions are usually made with finality by the attending physician in the contemporary clinical environment. In aerospace medicine, virtually everyone below the level of the final waiver authority only makes recommendations. In clinical medicine, the economic and lifestyle impact of mild diseases is frequently minimal. For example, the treatment of mild to moderate hypertension can usually be accomplished with minimal impact on the typical clinical patient, especially given the wide variety of antihypertensive therapies available. Failure of hypertension in the aircrew to respond to a limited number of agents usually results in a major career upheaval. In the rare circumstances wherein asymptomatic coronary artery disease is defined in a nonaviator, life usually goes on unimpeded. For the aircrew member, more than minimal disease is disqualifying for all categories of flying, and any degree of disease is usually disqualifying for high performance flying. In clinical medicine, our decisions are often driven by the desires and wishes of the patient. Regrettably, such factors often cannot be considered in the practice of occupational medicine.

Based upon all of these foregoing considerations, clinical decision making in aerospace medicine is vastly different from contemporary practice. Perhaps it would be helpful to review, in a quantitative sense, the disparate utility of each of

these factors in aerospace medicine compared to clinical medicine. (Table No. 3)

Table No. 3 ASSIGNING ARBITRARY VALUES TO THE COMPONENTS OF AEROSPACE MEDICINE AND DECISION MAKING

1 = Least favorable, lowest utility
2 = Less favorable, lower utility
3 = Favorable, moderate utility
4 = More favorable, higher utility
5 = Most favorable, highest utility

A score of 1 represents the least favorable circumstances, and the lowest clinical utility of the factor. A score of 5 indicates a very favorable factor of high utility. I have arbitrarily assigned the scores, based upon my own views and experiences. There is no factor in the aerospace medicine decision making process which I would score higher than 2, and only one factor in clinical medicine which I would score lower than 4. (Table No. 4).

Table No. 4 COMPARISON OF ARBITRARY VALUES IN AEROSPACE MEDICINE DECISION MAKING

	Aerospace Medicine	Clinical Medicine
Clinical State	1	5
Natural History Data	2	4
Prevalence of Suspected Disorder	1	4
Predictive Value of Diagnostic Tests	1	4
Disesae Subsets Defined	2	5
Outcome Data	2	4
Decision Goals	2	4
Decision End Point	2	4
Requirement to Make a Decision	2	5
Impact of the Decision	2	4
Surveillance and Retesting	1	5
Physiological Basis of Decisions	2	5
Pharmacological Data	1	5
Number of Decision Makers	2	3
Economic, Life Circumstances Impact on the Patient	2	4
Desires and Wishes of the Patient	1	5
TOTALS	26	70

I hope that this arbitrary scale will point out the very advantageous circumstances from which the usual clinician operates in the sick patient environment, while underscoring the relatively weak and restricted circumstances from which the

aerospace medicine specialist operates. By almost any standard, clinical practice is conducted upon a much more robust foundation than is aerospace medical practice.

Some of these disadvantageous aspects of aerospace medical practice are immutable, and unlikely to change. (Table No. 5)

Table No. 5 UNFAVORABLE ATTRIBUTES OF AEROSPACE MEDICINE DECISION MAKING UNLIKELY TO CHANGE, OR LESS AMENABLE TO CHANGE

1. Clinical state
2. Prevalence of suspected disorder
3. Predictive values reduced in asymptomatic (low prevalence) populations
4. Fly or not fly
5. Requirement to make a decision
6. Impact of the decision
7. Number of decision makers
8. Economic, life circumstances impact on the patient
9. Desires and wishes of the patient

However, we can focus on some aspects of aerospace medicine decision making which can actually be altered. (Table No. 6)

Table No. 6 UNFAVORABLE ATTRIBUTES OF AEROSPACE MEDICINE DECISION MAKING WHICH ARE AMENABLE TO CHANGE

1. Natural history data
2,3. Prevalence/predictive values
   - Laws of biostatistics will not be repealed, but stratification to increase pretest probability of disease is a much needed and useful strategy
4. Disease subsets identified
5. Outcome data
6. Surveillance and retesting
7. Physiological basis of decisions
8. Pharmacological data

Here, we have distilled down the list to a number of concrete factors which can actually be changed or influenced. If we are to improve clinical decision making in aerospace medicine, these areas represent the greatest targets of opportunity. As you will note, much of the needed change is in areas which revolve around data, areas in which we can truly influence the decision making process--natural history, stratification, outcome, subsets, physiologic data, and pharmacological data.

We have made great strides in physical standards, but we must conclude that for the most part the data base in aerospace medicine is incomplete, and is not yet built on a systematic knowledge base.

Since I am a cardiovascular specialist, please allow me to move to my area of interest in order to demonstrate the profound impact of technological advances on aircrew standards research. (Table No. 7)

Table No. 7 IMPACT OF NEW TECHNOLOGY ON AIRCREW STANDARDS RESEARCH

- Two dimensional, color Doppler echocardiography
- Trans-esophageal echocardiography Intracoronary ultrasound
- Intracoronary angioscopy
- Ultra fast CT for coronary calcification
- Multiple gated acquisition scans - technetium
- Thallium scintigraphy
- Sestamibi scans and first pass studies
- Dipyridamole, Adenosine studies
- Full disclosure Holter monitoring
- Radiofrequency ablation
- HDL and apolipoprotein subfractions
- Percutaneous coronary dilatation
- Percutaneous coronary atherectomy
- Digital subtraction angiography
- Magnetic resonance imaging
- Positron emission tomography
- Single photon emission thallium tomography

These technologies were not available in 1974, and yet we are using them daily in both clinical and occupational medicine. Any cardiovascular natural history study of asymptomatic persons started in the last 25 years has been profoundly affected by these technological advances. As the anatomy and physiology of the cardiovascular system are more clearly delineated, new subsets of disease and new categories of diagnostic precision have been added. As the nomenclature

of cardiovascular disease expands to include dozens of new cardiomyopathies, conduction diseases, and coronary disease variants, our precepts about asymptomatic cardiovascular disease in aircrew must change also. Essentially, this means that the task of aircrew standards research, including natural history studies, is never finished, even for diseases which we have known so well, because of both greater diagnostic power and the demands of steadily evolving weapons systems.

Unlike clinical practice, aerospace medicine practice is constrained by physical standards. We must view the standards as the governor, which requires us to make the same decision the same way each time until we have learned and acquired enough information to make the decision differently. Physical standards should not necessarily be revered for their inherent wisdom, since wisdom may not be in abundance. But, the physical standards are the indispensible decision rules which make air standards research possible. Data which are not gathered in a systematic fashion cannot be audited. Decision rules which do not exist cannot be changed. Since the "right decision" is often a cosmic unknown, it is far more important to make the decision the same way each time than it is to make the "right" decision. Those who are in control of aeromedical waivers in the application of physical standards are in critical positions, whether they realize it or not, because aircrew standards research is heavily dependent upon the clinical decision makers. If the decision makers create no matrix, no auditable trail, and no decision rules which can be prospectively tested, then the evolution of aeromedical standards becomes simply a process of visceral opinion. Such opinions are usually inconstantly applied, from which we can learn very little. There are actually areas of aerospace medicine wherein the world's great minds and the not so great are completely equal. It requires great professional and personal maturity, as the decision maker, to conform to decision rules. Physicians do not become physicians to do other than to make individual decisions and accept personal responsibility. On the other hand, aircrew standards research is best suited for the physician who can postpone gratification, since many long-term aircrew studies will come to fruition during someone else's professional life time. It requires great maturity for physicians to openly admit ignorance, especially in aircrew standards, where expert opinions and instant experts abound.

This grid, (Table 8,9) called the Cardiovascular Decision Grid, which was formulated by my former colleagues at the USAF School of Aerospace Medicine, Clinical Sciences Division, is actually a tacit admission of great ignorance. But, the grid is also the decision aid which assures that thousands of cardiovascular cases in aircrew members can be audited for outcome since like cases require like decisions. In any aeromedical center where large numbers of cases are seen, and especially in military centers where the professional staff changes regularly, very different decisions may result from identical data. Waiver decisions become subjective when history is not recorded, and there is no institutional memory. Decision rules require us to do our collective thinking well in advance for commonly evaluated problems. Such decision rules, made calmly and dispassionately, with our best understanding at that time, are invariably more fair, more uniform, and more intelligent than decisions made on a "one each" basis. The worst possible time to make new policy is when the decisions are driven by a current case, with all of the attendant pressures, emotional duress, and human insticts which surround decisions regarding a professional aviator's career. We are, after all, only human. Decision rules may be arbitrary, but we should never apologize for being arbitrary when we are following a system to acquire knowledge. We should, however, make apologies if our degree of ignorance is unchanged 10 years from now, because this would mean that we would not have served the aviator as well as we might have. A similar decision grid exists for neurological and psychiatric cases at USAFSAM. Areas which are heavily dependent upon multiple diagnostic testing are very amenable to the use of a grid. Everyone who uses a grid should be aware that some cases simply do not fit the decision rules. In any decision rule system, there is still plenty of latitude for innovative thinking. We need decision rules, but no system can foresee every circumstance in every aviator. Karl Jung made an elegant statement about the uniqueness of each individual. The evolution of every decision rule system should establish as the ultimate goal the decision best suited for the individual: "The shoe that fits one person pinches another. There is no recipe for living that suits all cases. Each of us carries his own life form which

cannot be superseded by any other." (Karl Jung) Without a decision rule approach to aeromedical standards, large generic opinion rules will place the individual at far greater disadvantage than a very mature decision grid which contains as many alternatives as possible. The aircrews will not benefit from advancing physical standards if we pretend to a wisdom which does not exist in place of a system to acquire wisdom.

Table No. 8

THE ACS CARDIOVASCULAR DECISION GRID

GUIDELINES FOR THE AEROMEDICAL DISPOSITION OF FLYING CLASS II
8 NOV 91

(1) NUMERICAL CODES (XYZ)		
X00-CARDIAC CATHETERIZATION STATUS	0Y0-WAIVER STATUS IF NO CAD	00Z-RETURN STATUS
1. NO AEROMEDICAL CARDIAC CATHETERIZATION REQUIRED. 2. LHC IF =>36 YO OR IF (<36 YO +RF) 3. (RHC+EPS) IF (<36YO -RF).(RHC+EPS +LHC) IF =>36 YO OR IF (<36 YO+RF 4. LHC 5. LHC THEN RHC + EPS. 6. LHC ALREADY COMPLETED	1. FC II WAIVER 2. FC IIA WAIVER. 3. DISQUALIFIED	0. NO RETURN 1. ONE YEAR 2. TWO YEARS 3. THREE YEARS 5. FIVE YEARS 6. THREE MONTHS 7. APPROPRIATE ACS & MEDICAL FOLLOWUP

(2) SAMPLE CELL	
CCC XYZ C	C=COMMENT XYZ-NUMERICAL CODE

(3) LIST OF DIAGNOSES/ABBREVIATIONS/DEFINITIONS

ABN	= ABNORMAL
AI/AS	= AORTIC INSUFFICIENCY/AORTIC STENOSIS
BAB	= BORDERLINE ABNORMAL
CAD	= CORONARY ARTERY DISEASE
FPR	= FREQUENT PAIRS. TWO ECTOPIC BEATS IN ROW AT A FREQUENCY OF >10 PER 24 HR HOLTER
LAH	= LEFT ANTERIOR HEMIBLOCK
LPH	= LEFT POSTERIOR HEMIBLOCK
LBB	= LEFT BUNDLE BRANCH BLOCK
LVH	= LEFT VENTRICULAR HYPERTROPHY (ANY WALL SEGMENT > 13 MILIMETERS THICK)
MAT	= MULTIFOCAL ATRIAL TACHYCARDIA (>=3 ATRIAL BEATS WITH >=3 FOCI WITH RATE >=100 BPM)
MCD	= MINIMAL CORONARY ARTERY DISEASE.
MFP	= MULTIFORM PREMATURE VENTRICULAR BEATS
MVP	= MITRAL VALVE PROLAPSE
NOR	= NORMAL
RBB	= RIGHT BUNDLE BRANCH BLOCK
RECURRENT	= SVT OR VT IS RECURRENT IF IT OCCURS MORE THAN ONCE DURING INITIAL WORKUP OR MORE THAN ONCE ON ANY OF THE SUBSEQUENT EVALUATION.
+RF	= PRESENCE OF CARDIAC RISK FACTORS
-RF	= ABSENCE OF CARDIAC RISK FACTORS
SSA	= SIGNIFICANT STRESS DYSRHYTHMIA DURING OR IMMEDIATELY AFTER EXERCISE IS DEFINED AS PAIRS (UNIFORM/MULTIFORM) OR 20% OF ANY 50 BEATS BECOME ECTOPIC
SVT	= SUPRAVENTRICULAR TACHYDYSRHYTHMIA (THREE CONSECUTIVE NON-SINUS SUPRAVENTRICULAR BEATS WITH RATE >=100 (SVT, ATRIAL FIBRILLATION OR FLUTTER)
VFR	= VERY FREQUENT ECTOPY (25% OF 1 HR OR 10% HOLTER)
VT	= VENTRICULAR TACHYCARDIA (ONLY 3 TO 7 BEATS IN SUCCESSION CAN BE WAIVERED)
WPW	= WOLFF-PARKINSON-WHITE PATTERN (NOT SYNDROME)

(4) LIST OF TESTS/ABBREVIATIONS

ECG	= ELECTROCARDIOGRAM
ECHO	= ECHOCARDIOGRAM
EPS	= ELECTRICAL PHYSIOLOGICAL STUDY
ETT	= EXERCISE TOLERANCE TEST
LHC	= LEFT HEART CATHETERIZATION
RHC	= RIGHT HEART CATHETERIZATION
THAL	= THALLIUM SCINTIGRAPHY

						137 B	AI	ECHO
					123 V A	137 B	MVP	ECHO
				637	621	637 B	MCD	LHC
			621	213 GM	223 AR	137 B	ABN	ETT
			621	113 K	123 A	137 B	BAB	ETT
215 M	215 M	621		213 MN	223 AR	137 B	ABN	THAL
110 E	215 M	621		113 K	123 A	137 B	BAB	THAL

Table No. 9

	LIST OF COMMENTS
A.	IF SEVERE AI OR AI DUE TO AORTIC ROOT DILATION, THEN 137.
B.	IF ATHLETIC HEART, THEN SAME CODE AS BASE CONDITION.
C.	ASSUMES DISAPPEARANCE OF LBBB/WPW PATTERN WITH EXERCISE.
D.	IF (LAH OR LPH) AND RBB, THEN 313.
E.	IF +RF THEN 113.
F.	IF ECTOPY DUE TO VENTRICULAR FOCUS THEN 137.
G.	IF SVT OR VT RECURRENT THEN 137.
H.	IF SUPRAVENTRICULAR PAIR THEN 112 N.
I.	IF >1 RUN <=7 BEATS THEN 113 J.
J.	IF >3 RUNS OF <=7 BEATS OR >1 RUN >7 BEATS THEN 137.
K.	IF THREE MONTHS WITHOUT RECURRENCE ON MONTHLY HOLTERS AND SVT PERSISTED <10 MINUTES THEN 213; IF SVT PERSISTENT >=10 MINUTES THEN 313.
L.	IF THREE MONTHS WITHOUT RECURRENCE ON MONTHLY HOLTER AND SVT PERSISTED <10 MINUTES THEN 223; IF SVT PERSISTED >=10 MINUTES THEN 323.
M.	IF <36 Y.O. AND -RF THEN 113.
N.	MONITORED CENTRIFUGE RIDE IF HIGH PERFORMANCE AIRCRAFT PILOT OR NAVIGATOR.
P.	IF >1 RUN =<7 BEATS THEN 213J.
R.	IF <36 Y.O. AND -RF THEN 123.
S.	IF ATHLETIC HEART ONLY THEN 110.
T.	IF >1=<7 BEATS THEN 123J.
U.	IF <36 Y.O. THEN RETURN AT 36 Y.O. OR IN 5 YEARS, WHICHEVER IS LONGER.
V.	IF EVIDENCE OF A GENERALIZED MYXOMATOUS PROCESS, THEN 137
W.	IF RUN <= 7 BEATS AND IF THREE MONTHS WITHOUT RECURRENCE ON MONTHLY HOLTERS, THEN 221; OTHERWISE 137.
X.	IF RUN <= 7 BEATS AND IF THREE MONTHS WITHOUT RECURRENCE ON MONTHLY HOLTERS, THEN 421.
Y.	IF < 36 Y.O. AND -RF THEN 115

ELECTROCARDIOGRAPHIC FINDINGS	RBB	LBB	WPW	MAT	VFP	FFR	SVT	VT	THAL BAB	THAL ABN	ETT BAB	ETT ABN	LHC MCD	ECHO MVP	ECHO AI	ECHO LVH
VT									WJ 136	XG 136	WG 136	XG 136	637	137	AWG 136	B 137
SVT								137	GK 136	GK 136	GK 136	GK 136	637	137	AGL 136	B 137
FFR							GK 136	137	113	H 213	113	M 213	621	137	A 123	B 137
VFP						137	GK 136	137	113	M 213	113	M 213	621	N 112	A 123	B 137
MAT					IJ 113	IJ 113	GIJ 136 K	GIJ 136 W	IJ 115	JPY 215	IJ 115	JPY 215	621	N 113	AJI 123	B 137
WPW				IJ 115	112	112	137	137	115	Y 215	C 115	CY 215	637	137	A 123	B 137
LBB			137	IJ 513	512	512	137	137	513	513	C 513	C 513	637	N 513	513	B 137
RBB		D 137	115	IJ 115	113	113	GK 136	WJ 136	110	U 215	110	U 215	621	N 113	A 123	B 137
NO SECOND DIAGNOSIS	110	513	115	IJ 115	113	113	GK 136	WJ 136	110	U 215	110	U 215	621	N 113	A 123	S 137

(6)

THIS GRID WAS CREATED TO ENSURE CONSISTENT APPROPRIATE EVALUATION AND RECOMMENDATION FOR FLYERS EXAMINED AT THE AEROMEDICAL CONSULTATION SERVICE. THIS WAS NOT MEANT TO REPLACE COMMON SENSE OR CLINICAL JUDGEMENT. INDIVIDUAL PATIENTS SHOULD HAVE ADDITIONAL TESTING OR MORE FREQUENT EVALUATION AS THEIR RISK FACTORS OR THEIR CLINICAL CIRCUMSTANCES WARRANT.

As we look for ways to improve aerospace medicine decision making, we must focus physical standards research on the inevitable information voids in aerospace medicine which most directly affect clinical decision making. (Table No. 10)

Table No. 10 THE INFORMATION VOIDS

- Natural history studies
- Merging of medical epidemiological data and flight safety/training data
- Physiological data on subclinical processes in aircrew

The greatest information voids are in natural history studies of asymptomatic disorders, the merging of medical epidemiological data with flight safety and training data, and physiologic data on subclinical processes in aircrew. Let us focus for a moment on the physiological data information void. Throughout the NATO air forces, our physiologists have made incredible strides in the areas of acceleration and high altitude protection, as well as thermal and chemical protection. In the area of cardiovascular waivers alone, we cannot completely settle issues regarding asymptomatic arrhythmias, mild valvular disease, and asymptomatic coronary artery disease from an epidemiological and natural history standpoint alone. We are steadily proving that many of these disorders are completely compatible with flying in terms of natural history outcome, but what about the effects of +Gz as well as anti-gravity/thermal/chemical protective equipment on the underlying disorder? We clinicians in aerospace medicine must present our colleagues in physiology with well thought out questions about subclinical disorders, believing that experimental models can be created to address the relevant clinical questions.

Table. No. 11 MANY DIFFICULT CLINICAL ISSUES ARE A DIRECT RESULT OF POOR SELECTION

- Congenital diseases
- Personality disorders
- Risk factors
- Poor motivation
- Psychomotor skills

YET, MOST CLINICAL ATTENTION IS FOCUSED ON AIRCREW RETENTION.

The great majority of our research in clinical aerospace medicine has been spent on the retention of experienced pilots. Very few outcome studies exist, for any body system, in the area of pilot selection. We have extensive selection batteries, but few of them have been tested in a longitudinal fashion. Many difficult clinical issues in the trained aviator are a direct result of poor selection. We must focus greater attention on selection research, formulating a selection system which can be audited for outcomes of interest.

Table No. 12 outlines the salient differences between selection and retention research.

Retention research has largely dominated the landscape, and yet selection research is the simplest, quickest, least expensive, and more effective research in terms of return on investment. In a period of declining budgets and greater emphasis on resource management, selection research offers the greatest return on the investment of scarce funds.

Table No. 12 SELECTION VS. RETENTION RESEARCH

SELECTION	RETENTION
Relatively short duration	Long duration
Relatively inexpensive	Very costly
Large denominator	Small denominator
Great statistical power	Usually low power
Cost savings immediate	Expensive waiver system
Prevents training low investment resource	Retains a valuable resource for a brief period

Table No. 13 THE GREATEST NEEDS OF THE AEROSPACE MEDICINE CLINICIAN IN SELECTION AND RETENTION

1. Outcome information (cofactors and endpoints on trainees
2. A validated coronary disease discovery system based upon stratified testing
3. $+G_Z$ effect on subclinical cardiovascular disorders

Based upon my observations, I believe that the greatest needs of the aerospace medicine clinician in the nonpharmacological arena are in the area of selection outcomes for all body systems, a stratified coronary disease discovery system in trained aircrew, and the effect of $+G_Z$ acceleration on subclinical cardiovascular disorders. (Table No. 13)

Cardiovascular problems constitute between 50% and 66% of all retention cases, but psychiatric, ophthalmological, and neurological cases could easily be given high priority.

The mission of AGARD is broad and we have all been exposed to the mission statement. (Table No. 14)

Perhaps the foundation for research cooperation in AGARD will give rise to new opportunities. No NATO member has the resources to actively pursue all areas of aerospace medicine research. And, no member currently has the denominator to answer all of the relevant questions. Is it possible that AGARD can move beyond the sponsoring of superb symposia, move beyond the production of erudite position papers, and move beyond the sharing of research products? Is it possible for AGARD to become a driving force in the creation of data by sponsoring selected multinational aircrew standards research projects, rather than serving solely as a conduit of information and a sponsor of position papers? If the AMP had not done such a splendid job as a technical advisory group and educational organization, no one would contemplate urging this organization to widen its horizons. But, excellence has its rewards, and in some ways its burdens.

When an organization has sponsored excellent science in an atmosphere of fellowship, it attracts many men and women with dreams and visions. And now, the AMP has many of our hopes riding on its shoulders. No one is suggesting that AGARD change its charter, but we must recognize that the AMP is in a unique position to sponsor true multinational research projects with pooled data in a number of carefully selected

Table No. 14 THE MISSION OF AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

Table No. 15 THE AGARD OPPORTUNITY

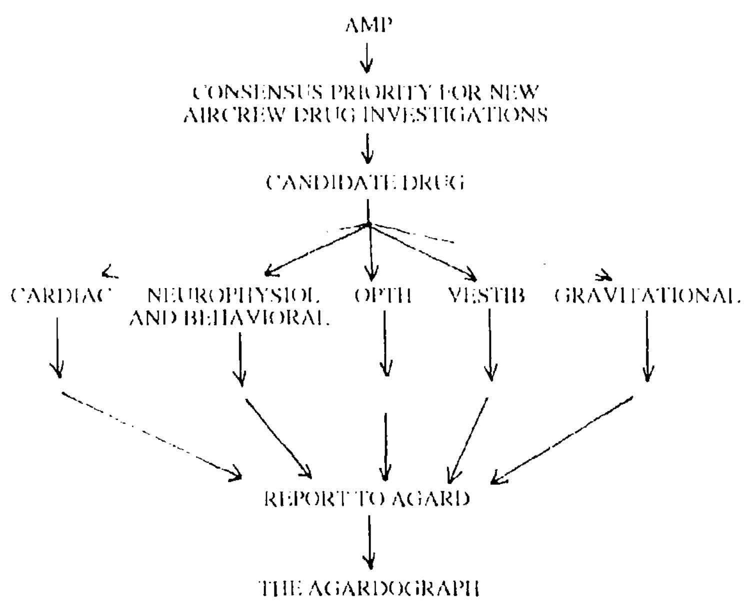
- Take advantage of the denominator offered by the NATO aircrew population
- Foster cooperative long term research in aircrew standards
- Encourage and promote basis sciences research which addresses information voids in clinical aerospace medicine

projects. It does not matter if it takes a period of learning to have such projects, the rewards are potentially enormous. Why should we make our decisions about head injury, for example, a common aeromedical problem, based upon a series of patients from University "A" or Hospital "B", totally unlike an aircrew population? Why should the aviation community not be reading the "NATO Head Injury Study"--a collaborative study of 500 aviators with standardized followup in an AGARD sponsored study? NATO has the talent and the clinical denominator to do it. The issues are too important not to do it. The AGARD opportunity is outlined in Table No. 15.

AGARD has an opportunity to capitalize on a huge denominator, producing data of great interest outside aeromedical circles. The transitional value of such data to the civilian community is a benefit which will not go unnoticed by those who are seeking the relevance of military research and development to the civilian sector. Our basic scientists should be challenged to deal with the concerns of clinicians about low grade diseases.

Figure No. 1 is a simple schema for NATO drug testing.

Figure No. 1



Why do I advocate the AMP as the coordinator of multiple centers of excellence in pharmacologic research of specific body systems, with candidate drugs being evaluated in parallel in multiple centers? Bringing new drugs to the flight line is occurring at glacial speeds - far too slow to meet the emerging needs for lipid lowering drugs, antihypertensives, antimalarials, and circadian rhythm drugs, to mention but a few. Every NATO member has pharmacological areas of excellence - neurophysiology in one country, cardiovascular in another, human performance in another, acceleration in another, and so forth. At USAFSAM when I led a clinical division of 185 personnel, the purely clinical evaluation of a drug required the full division strength for at least six months, which, of course, you could never do. So, months turned into years. If each of several nations had specific areas of excellence, candidate drugs, decided upon by a consensus of working flight surgeons, could be studied in parallel, with great economy and rapid results. We are falling farther behind in new and old drug testing. Scientists throughout NATO who wish to do epidemiological, pharmacological, clinical or basic research in a collaborative fashion need sponsorship and a forum, which AGARD is uniquely positioned to furnish.

What will be the rewards for seizing the AGARD opportunity?

Because I believe that one can only take home from any lecture a very limited number of ideas and concepts, this statement I would like for you to remember:

VIRTUALLY EVERY QUANTUM LEAP IN THE UNDERSTANDING OF SUBCLINICAL DISEASES OR ABNORMAL TESTS IN AIRCREW HAS LED TO A LIBERALIZATION OF FLYING STANDARDS

During my career in aerospace medicine it seemed to always be true that with every significant leap in information, some subset of aircrew members benefited from liberalized standards. Valuable resources are saved, personal careers are continued. Here is where you can do the greatest good for the desires and wishes of the aircrew, a factor often denied us in dealing with individual aircrew.

Thank you for allowing me to open this symposium of the AMP. There is no organization which has had a greater impact on my professional life, and none which has produced greater friendships. The shared experiences of AGARD colleagues over many years is the very heart of aerospace medicine in NATO. In a changing world, with changing military missions and new orientations for the alliance, we must maintain our forum for these shared experiences. Without the panel, we will have no common ground, no platform, no medium, and none of the sentiment which binds allies together. There is no replacement for having travelled together, having stood in each other's kitchens, and meeting together as we do this week. From such things are great alliances made. I am very proud to be one of you. I wish you good health, good flying, and a good meeting. Thank you my friends.

AEROMEDICAL RISK MANAGEMENT FOR AIRCREW

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SUMMARY

Medical waivers for aircrew are exceptions to aeromedical standards which have operational justification. The goal of the waiver process is to preserve flying experience to the fullest extent while preserving flight safety, individual health and mission completion. Unfortunately, the flight surgeon has historically been forced to be conservative in deciding who was or was not fit to fly because of a paucity of relevant scientific data. Moreover, the waiver process has not always been applied logically or consistently. The US Air Force has recently applied the philosophy of aeromedical risk management to produce a waiver guide for flight surgeons. The guide lists the aeromedical concerns for selected chronic conditions met by the flight surgeon. Advice is given on the workup required for each waiver request and a discussion section examines the rationale for the aeromedical disposition. For each condition, an indication is given of the US Air Force waiver experience over the last few years. This paper examines the basic philosophy and describes the use of the waiver guide.

1 INTRODUCTION

During this century, we have progressed from Kitty Hawk to the moon, from overcoming 1G to prolonged exposure to zero G or very high G, from bicycle goggles to night vision goggles. As man found himself at higher altitudes, at greater speeds and in more challenging cockpits, the flight surgeon was required to make decisions about the aviator's fitness to fly with limited experience or scientific data on which to base these decisions. One step forward was the realization that flight surgeons could make a difference; for example the formation of the Special Royal Flying Corps Medical Board in 1916 significantly improved the proportion of candidates who were successful in flying training (1). Thus aviation medicine has been in the business of risk assessment and risk reduction from the very beginning.

More recently, the results of long term studies of aviators, and collaborative efforts in aeromedical research within the international community, have given us the evidence to advance from our original conservative, intuitive approach. Aerospace medicine risk management can now be applied to make more informed recommendations whilst preserving the primary goal of flight safety.

This paper examines, in general terms, the philosophy behind aeromedical decision making and how that philosophy has been applied in the US Air Force.

2 MEDICAL STANDARDS

Aeromedical standards are promulgated in order to identify individuals at potentially increased risk of incapacitation or performance decrement. Before an aviator with a medically disqualifying condition can be returned to flying duties, he/she must be granted a waiver. Waivers are exceptions to medical standards which have operational justification. Waiver policy seeks to balance risks to individual health, flying safety and mission completion against conservation of resources, flying experience, training costs and leadership development. This balance will shift over time depending on social, political and economic influences.

To be considered for waiver, a medical condition must meet the following criteria:

a. There must be minimal risk of sudden incapacitation.

b. There must be minimal potential for subtle performance decrement, particularly with regard to the higher senses.

c. The condition must have resolved or be stable and be expected to remain so under the stresses of the aviation environment.

d. If there is a risk of progression or recurrence, the symptoms must be easily detectable and must not pose a risk to the safety of the individual or others.

e. The condition must not require exotic tests, regular invasive procedures or frequent absences to monitor for stability or progression.

f. The condition must be compatible with performance of sustained flying operations in austere environments worldwide.

The use of the word "minimal" recognizes that zero risk is impractical and would, incidentally, exclude most of the aircrew who presently have waivers and who have performed effectively over thousands of flying hours. Civilian aviation authorities have set a goal of less than one fatal accident in multicrew aircraft for each 10 million flying hours (2). Bennett (3) proposed that the contribution to this from medical incapacitation should be 10%, that is medical incapacitation should cause fewer than one fatal accident for each 100 million flying hours. This target is achievable if the risk to a pilot of incapacitation is less than 1% per year (4). The risk can be manipulated by increasing the number of pilots. If the risk of one pilot being incapacitated by a heart attack during a one hour flight is 1 in 10^6, then the risk of two being so incapacitated will be 1 in 10^{12} (5). This assumes that both are not vulnerable to the same precipitating stress and that incapacitation of one pilot does not prevent the second pilot from recovering the aircraft. The US Air Force is unwilling to endorse formally such a "shared risk" approach in its waiver policy primarily because pilot and copilot are not considered to be equivalent positions. Moreover, the risks are higher in operational, single-seat, military flying. Although the US Air Force has set no specific goal, McCormick & Lyons (6) calculated a rate of incapacitation of 0.19 per million aircrew flying hours for the period 1978-1987.

3 WAIVERS

Waiver decisions are thus based on an awareness of these principles, prior experience based on waiver precedents, available scientific research and, ultimately, expert aeromedical judgement. Waiver decisions are individually rendered.

Types of Waiver. The following different waivers are possible at present in the US Air Force. **Flying Class I** waivers qualify an individual for flying training, **Flying Class II** for unrestricted pilot, navigator or flight surgeon duties and **Flying Class III** for all other aircrew positions. In addition there are restricted Flying Class II, or "**categorical**" waivers. **Flying Class IIA** restricts an airman to tanker, transport or bomber aircraft to limit exposure to $+G_z$ stress. **Flying Class IIB** restricts an aviator from ejection seat aircraft. **Flying Class IIC** is used when the waiver is tailored to a particular circumstance, for example to specify "no mobility" or "flight only in helicopters." Flying Class IIC waivers are given only with the concurrence of the operations community since they significantly limit the individual's mission availability. This consideration process keeps waiver decisions honest with regard to "operational justification."

Aeromedical decision-making in the US

Air Force is largely decentralized and occurs at many levels. Basic medical qualification standards are written at HQ Air Force Medical Operations Agency (AFMOA) in cooperation with the Aeromedical Consultation Service at Brooks Air Force Base. These standards are applied by flight surgeons at the base level. When waivers are necessary, workup and documentation are forwarded to the major command (MAJCOM) headquarters or HQ AFMOA for waiver decision. Thus the waiver decision involves input from general flight surgeons, clinical specialists and aerospace medicine specialists.

4 THE WAIVER GUIDE

Because many general practice flight surgeons are inexperienced and waiver authorities at HQ change every 2-3 years, significant inconsistency has existed in the quality of waiver requests and in waiver decisions. A waiver guide (AFPAM 48-132, "Medical Waivers for Aircrew" [7]) has been written to place the same information before all the elements involved in waivers and also to provide a mechanism for handing on collective, historical experience with waiver decision making. We expect "Medical Waivers for Aircrew" to improve three aspects of aeromedical practice: consistency, currency and comparison. A sample page from the guide is at Annex A.

The waiver guide combines waiver precedent data from 2 US Air Force data bases, the HQ AFMOA waiver file and the Central Waiver Repository at Brooks AFB. The former contains all cases referred to AFMOA since 1985 while the latter purports to contain all waiver actions within the US Air Force; experts consider this file to be up to 25% incomplete. Pertinent information on prognosis is included for each disease. Thus all medical personnel in the process start with the same baseline information. This offers both the opportunity and the challenge to all involved to submit updated information in support of a given case or for incorporation into the waiver guide. The format of the guide was selected to allow for single-page replacement to facilitate revision. A future version of the guide, including references, is nearing completion.

Moreover, the guide, by collecting risk analysis data into one source, invites comparison of risks between different diagnoses. For example, one might consider risk of seizure a significant aeromedical concern. One can turn to the waiver guide to find the following:

> Melanoma - risk of symptomatic CNS metastasis is 2-3% at one year
>
> Blunt head injury with 24 hr LOC is 7% at one year

Knowing that the risk of new onset seizure in the unscreened population is approximately 0.5-0.8% (8), we would be reluctant to grant a waiver in a case where the known risk significantly exceeds the population in general. Certainly careful screening has substantially reduced the risk of idiopathic seizure in the aircrew population. In the past, decisions about given conditions would have been considered separately. Had we been waivering severe head injury at one year, but not melanoma, we would have been inconsistent - in the absence of other mitigating factors.

In its presentation, the waiver guide seeks to draw information from relevant populations. For example, supraventricular tachycardia (SVT) in patients with heart disease has very different implications than SVT in a healthy aviator and diverticulitis in young patients is associated with significantly increased risk of complication compared to older patients (9).

The waiver guide also provides a rational approach to decision making with regard to waiver for use of medication and history of malignancy.

5 USE OF MEDICATIONS

The requirement for long term

medication necessitates careful preparation of the waiver request and the use of drug therapy in aviation requires strict control. Most therapeutic agents have unwanted side effects, some of which may become more hazardous in the aviation environment. For example, a drug that produces arteriolar vasodilatation may be expected to reduce tolerance to $+G_z$. Many over-the-counter cold medications contain antihistamines that produce drowsiness. Side effects of drugs may not be fully appreciated at the time of first marketing, for example the dysrhythmic effect of the non-sedating antihistamines. This is why US Air Force aircrew on medications will usually be grounded until the medical condition has resolved, the medication is no longer required and the effects of the drug have dissipated; they must be cleared to return to flying duties by a flight surgeon.

US Air Force regulations contain 3 lists of medications: those which the aircrew member may use without consulting a flight surgeon, those which the flight surgeon can prescribe without removing the individual from flying duties, and those which can be routinely waivered. All other medications are considered for waiver on a case by case basis. The use of some medicaments has been hallowed by antiquity. They would not be approved now without extensive investigation because of the documented side effects. It must be admitted that there is little evidence that harm has been caused. However, it is still necessary to take a conservative approach to new additions to the pharmaceutical armamentarium for aircrew.

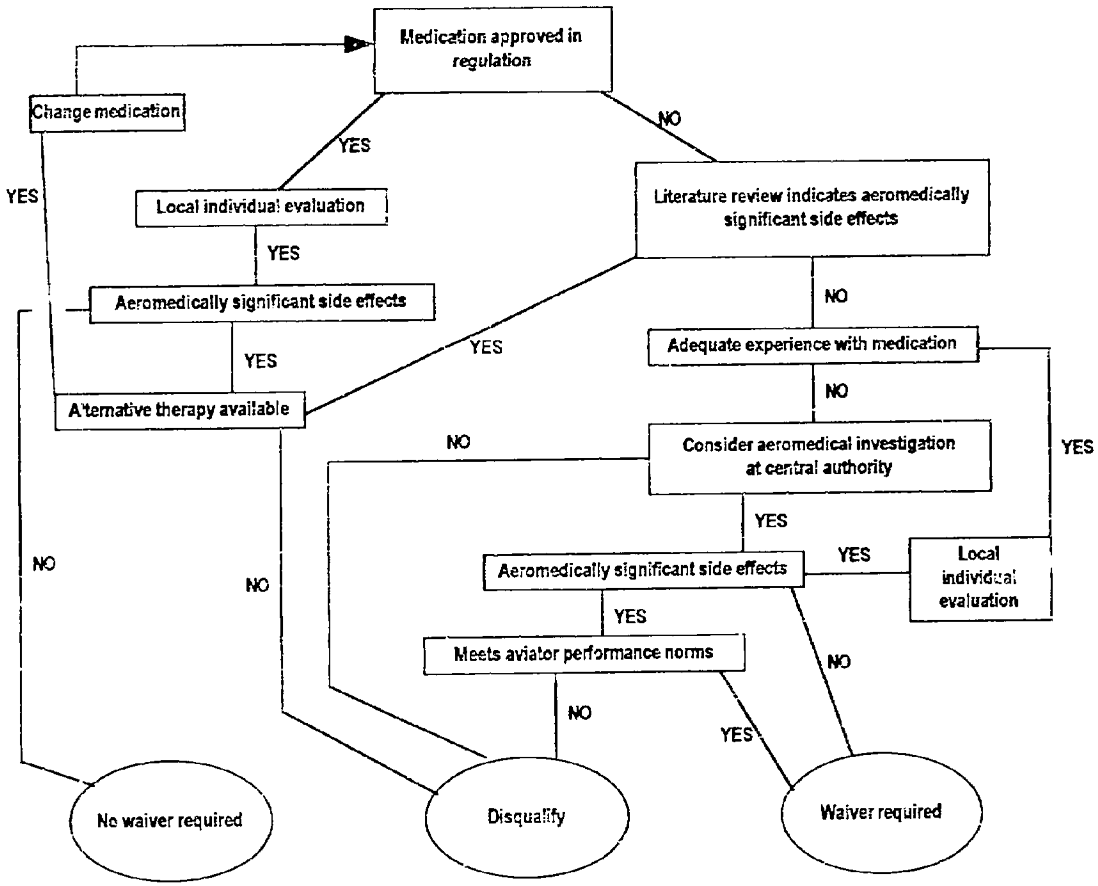
It is less important to justify past inclusions to the approved lists than to establish a consistent approach to the decisions about new waivers. The algorithm at Figure 1 illustrates the basic questions posed in the waiver guide. Sometimes it is the underlying condition and not the medication which drives the requirement to obtain a waiver. Even if the medication is approved without waiver, the patient needs a ground trial to exclude idiosyncratic reactions. If a waiver is required for an approved drug, a ground trial is still needed to rule out aeromedically significant side effects. The underlying condition must be waiverable, the efficacy of the treatment should be demonstrated and the flight surgeon should conduct appropriate monitoring. The process of granting a waiver for a new medication must begin with a comprehensive literature search for aeromedically significant side effects. If these are found, or experience with the drug is limited, a formal drug investigation should be undertaken. This may be either a research protocol to identify any adverse effects of the medication or an in-depth assessment of the individual on the medication. If the aircrew member can meet aviator performance norms, a waiver could be granted even though some subtle side effects may exist. The US Air Force has adopted the latter approach to granting the first waivers for Lisinopril.

6 MALIGNANT DISEASE

Classification. Classification of tumors into categories facilitates decision making on aeromedical outcome. The minimal requirements are accurate diagnosis, indication of tumor size, differentiation and local invasion, and confirmation of the presence or absence of lymph node or distant metastases. Further classification gives some indication of the virulence and potential for relapse. To provide standardization in disposition of these cases, it is essential for the histology to be confirmed by a reference laboratory; in the USA, this is the Armed Forces Institute of Pathology (AFIP). In a review of the last 17 cases of neoplasm, AFIP diagnosis differed significantly from local opinion in 6 patients (35%).

Effects of Treatment. The impact that a cancer has on an aviator requires not only consideration of the organ of origin but also the clinical or surgical stage and the treatments that are being or have been used. Aircrew

Figure 1. Algorithm for medication approval in aircrew.



with a history of malignant disease are not considered for waiver until all treatment is complete and the individual is judged clinically disease free. Sufficient time must have elapsed from the completion of treatment to assure that late complications do not develop such as cardiac or pulmonary toxicity from chemotherapeutic agents.

Waiver Consideration in Malignancy. Waiver consideration focuses on the nature and frequency of the required follow-up, the projected 5 year survival rate and the nature and risks of local recurrence or of CNS or other potentially incapacitating metastasis. For the vast majority of tumors, Tumor Board evaluation and Medical Evaluation Board (MEB) recommendations are essential before waiver consideration can be given. These Boards supply information on prognosis and appropriate follow-up of malignancies as well as advice on the general suitability of the individual for continued military service. The necessity for follow-up will almost certainly interfere with mobility requirements unless the follow-up is at greater than 6-monthly intervals or the tests required are very simple, e.g. complete blood count (CBC).

In general terms, the waiver authorities will try to obtain a return to restricted flying status as long as there is a minimal risk of incapacitation as a result of recurrence. In many cases, upgrading to a less restrictive waiver can be considered 2 years after completion of therapy provided there is no recurrence. This decision will include an assessment of survival and recurrence rates. Waivers are not generally granted for metastatic disease or cases with a 5 year survival rate of less than 90%. This number is arbitrary, but incorporates the economic reality that it is cheaper to replace an aircrew member at the time of diagnosis than at a higher experience level 3 or 4 years later if a cure was not achieved. From a risk/benefit standpoint, 90% may be too strict.

7 CONCLUSION

Considering an aviator's fitness for flying in the presence of disease is a complicated business. Many factors combine to obfuscate the issues. For the flight surgeon, the process is as much an art as a science, with mutual trust and respect with the fliers playing as important a part as pure knowledge. Other more rigorous and quantitative proposals for waiver decision making have been proposed elsewhere. The Froom and colleagues have attempted to quantitate age and the experience factor in relation to aviation safety in the Israeli Air Force. They concluded that even a tenfold increased incidence of disease-related sudden incapacitation would yield a lower overall mishap rate than replacing a 30 year-old fighter pilot with a novice (10). Clark has applied Decision Analysis to neurological cases in the US Navy and found it a useful adjunct in aeromedical disposition (11). However, many of the numbers upon which the decision tree is built are subjectively determined. Although statistical risk modeling is valuable, it cannot substitute for sound aeromedical judgment. The social, ethical and political ramifications can be substantial for a preventable, medically-related mishap--even when the statistical risks were calculated to be very small. For the present time, we believe a team decision process offers the potential of the highest quality decision and that the waiver guide will enhance the effectiveness of each member of the decision team.

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CONDITION: THYROID CARCINOMA

A6.13. Aeromedical Concerns. There is a substantial risk of hypothyroidism after surgical treatment. A small risk of damage exists to recurrent laryngeal nerves from local invasion and of surgical damage to the parathyroid glands.

A6.14. Waiver. Waiver will be considered after treatment of papillary or follicular carcinoma of the thyroid. Medullary or undifferentiated thyroid tumor will normally lead to DQ.

A6.15. Information Required. Tumor Board recommendations and MEB are required. AFIP confirmation of the histology is mandatory. Confirmation of euthyroid status and evidence of TSH suppression are also needed for initial and renewal waiver action.

A6.16. Treatment. Surgery. Some authorities prefer to use ^{131}I treatment.

A6.17. Discussion. Generally, men over 40 years old and women over 50 have a worse prognosis. Another poor prognosticator is a primary tumor over 5 cm. **Papillary** carcinoma is slow growing, spreading locally to the strap muscles of the neck, lymph nodes and occasionally trachea but it may metastasize to lungs or bone. Some 20% are said to be multicentric. Overall 5/10 year survivals of better than 95/90% can be achieved. Because the growth rate is slow, there is no particular trend to early recurrence (recurrence rates from 10-24% have been reported); patients should be able to return to flying as soon as they are euthyroid. **Follicular** carcinoma tends to metastasize to lungs and bone rather than infiltrate locally. A major determinant of outcome is the extent of microinvasion. The usual treatment of choice is total thyroidectomy because there is an 87.5% chance of the opposite lobe containing microscopic follicular carcinoma. For patients treated with total thyroidectomy and radioactive iodine, the death rate at 5 years is quoted as 11%, rising to 30% when treatment is by incomplete thyroidectomy alone. This can be largely explained by the fact that only total thyroidectomy allows subsequent accurate localization and treatment of distant metastases by ^{131}I. **Medullary** carcinoma and undifferentiated carcinomas have a 10 year survival of 50 and 20% respectively.

A6.18. US Air Force Experience. So far, all aircrew with thyroid carcinoma have eventually been granted a waiver to return to flying.

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The way to waivers in the BAF

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Introduction

The medical and physical examinations our pilots go in for at recruiting and during their annual revision become more extended and accurate thanks to new medical techniques. On the hand we notice that the importance of human factors as a cause of flight accidents increases.
Therefor the medical Commission responsible for declaring pilots fit to fly has to describe the affections regarding to risks and prognosis more detailed, and has to impose flight restrictions adapted to the type of airplane and the function of the pilot involved.
The medical Commission for suitability to fly 's decision thus has an important influence on the further career of the pilot in question and on flight safety in common. The Commission has to find a balance between common and personal interest.
The main intention of this study was to critically evaluate the procedures followed by the Commission, based on an investigation on the cases of all pilots of the Belgian Airforce, who were restricted definitively during the year of 1992. The population, the different kinds of affections and the resulting flight restrictions were studied. These data will be followed by a critical view on the method of procedure of the Commission.

Methods

All flying personnel of the Belgian Airforce is scheduded to an annual medical examination in the Aerospace Medical Center in Brussels.
This examination consists of an interrogation, including the data obtained by the flight surgeon, a complete medical examination, a Thorax radiography, Pulmotests, different lab-tests, audiometry and ECG.
Medical capability is decided upon in case of a normal investigation. The Commission (GCGLuD) consists of three appointed and nominated medical doctors, specialized in Aviation Medicine, and part of the Medical Center.
Besides this medical Commission, a Commission of Appeal exists.
If affections are detected during such an annual examination or if the pilot is referred to the Commission, by his flight surgeon, to evaluate his fitness, or even on request of the pilot himself, or his commander, the GCGLUD can decide upon a flight restriction that may get definite.
During the year of 1992, 43 members of the flying personnel (FP) of the BAF (41 pilots and 2 navigators) had a flight restriction due to a medical reason. Those FP's medical records were checked upon, and analyzed for personal data, medical problems, method of function of the Commission and final decision.

Results

Personal data

In 1992, the flight restricted population counted 43 people out of 519 flying personnel in the BAF, or 8.3 %.
The average age of this group was 44 years. Mean age of the total population was 35 years.
To get an idea if age or career are significant, the initial age and the corresponding rank on the moment of the first restriction were checked upon (Table 1)

PERSONNAL DATA

	Total Population	Restricted Group Initial	Restricted Group Final (1992)
N	519	43	43
Mean age (Y)	35	34	44
Ranks(officer)			
Superior	151 (29 %)	12 (28 %)	15 (34 %)
Commander	177 (34 %)	9 (21 %)	22 (52 %)
inferior	191 (37 %)	22 (51 %)	6 (14 %)

Table 1. Personnal Data of the Total FP compared to the group with restrictions.

Mean age was 34 years (SD 7.5).If we compare the initial with the final rank of the 43 FP in 1992, we notice that the number of commanders is pretty high 52 %.

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The average number of flyinghours initially was 2286 h (SD 1233, min 400 h, max 5900 h)
The type of aircraft was spread over the different kinds used at that moment
We noticed that the population studied always had sufficient flight experience, mostly in different types

Affections

Although these data are hard to be checked upon one file, it is quite remarkable that the affection is often noticed for the first time during the annual examination (22 cases) In 1 case it was the pilot himself who asked to be able to appear for the Commission; 9 cases were first examined by a civil doctor, 11 by their own flight surgeon (fig 1 source)

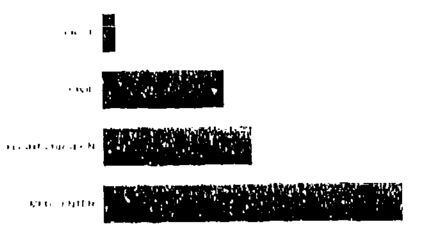

Fig.1 Source First presentation of the limiting affection

In most cases it was a disease (n 37 or 86 %), 4 (14 %) were evoked by an accident
A more thoroughly analysis of the affections conclude to 7 organic systems that lead to the final restriction (fig 3) In 10 cases, 2 systems were involved, mostly by the impact of one system on the other
Most important is the cardiovascular pathology 15 (29 %), followed by orthopedics 9 (17%) ophthalmologic 8 (15 %), common internal diseases 8 (15 %), and finally neurologic 4 (8 %), psychologic 4 (8 %) and ORL diseases 4 (8 %)

Fig 2. Organic System: distribution of affections causing restrictions

A more detailed revision is given in table 2. Remarks illustrate the specific diseases This is important to understand evolution in certain diseases, and a resulting delay in final restriction
In those 43 cases, the disease started 26 times rather acute, in 17 cases a chronic development was seen
We were able to find pre morbid factors in 10 cases

Table 2 [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Vertebral pathology	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Decision of the Commission

The final restrictions that allowed 43 people of our FP to fly any way during the year of 1992, are given in fig 4 Totally there are 82 restrictions. 18 pilots had only one restriction while 25 others had several In 33 cases, the type of aircraft was specified
In 14 cases wearing glasses was required. Notice that those people also had another restriction. Beside these 14 pilots, 24 others - not mentioned in this paper - had visual problems, leading to a requirement to wear glasses
In 13 cases, the requirement demanded that involved FP could only fly as a co-pilot together with another - non-restricted- pilot

The duration of ability got in 12 cases restricted to 6 months, in order to be able to re-examine the pilots regularly.
Other restrictions are : countries to which is being flown, (3 for nutritional problems) and restriction of G acceleration (1 for barotrauma, 1 for syncope, 1 for hypertension). One pilot was declared unable for flights in planes with ejection seat (back problem), one unable for Acrobatics (one of the restrictions of our pilot with coronary bypass), one restricted in duration of flights (back problems) and one in height (emphysema).

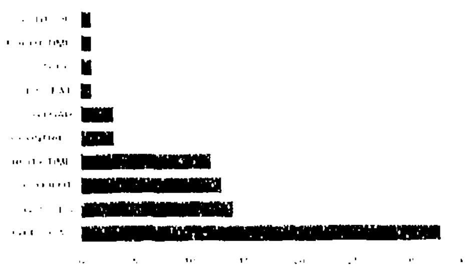

Fig 3 : Final restrictions. Number of different kinds of restrictions.

Discussion and conclusion

By centralizing the examinations of the FP of the BAF, annually in our Medical Center, the Commission is able to screen all FP more thoroughly and neutral. This explains the fact that 51 % of all affections are initially discussed or noticed at the Center.
The flight surgeon on the other hand is placed in a delicate position of confidence in which - within the limits of safety - he will try to keep his pilots airborne.
He is an irreplaceable counselor for the pilot. He's able to accompany the pilots for the Commission and even to defend them without loosing the confidence of his pilots.
From the results of this study, one notices that all age groups and all aircraft types are represented equally in the group of FP with flight restrictions.
The restriction itself nonetheless has undeniable a negative influence on the further career of the pilot.
The Commission tries to avoid this as much as possible by specifying and detailing the restrictions, eventually by discussing them with the command.
From an analysis of the affections, it shows that it are mainly diseases that are the cause of permanent restriction (86 %).
The frequent damages that occur with the FP by accidents (especially traffic or sport accidents) mostly lead to temporary incapacity and only for 14 % to definitive restrictions by sequels.
The fact that the medical examination has to be as accurate as possible and also has to include additional technical and lab examinations appears from the diversity of affections.
Our center has the advantage of being able to systematically perform all the examinations on a basic routine and only exceptionally having to refer to the Central Military Hospital of Brussels (HMKA) for survey.
The treatment of the pilots, and the examinations that go with it, are being coordinated by the Flight Surgeon, and take place in civil hospitals or the Military Hospital. Therapy and evaluation of flying ability stay separated this way.
The specific pathology is shown in fig 3 and table 2.
The importance of cardiovascular diseases is remarkable (29 %). This justifies the further extension of our examination facilities with spiroergometry and echocardiography for early detection and to admit safe flying continuity.
Further reflection on risk factors (hypertension, hypercholesterolemia, ...) on security enhancing examinations and on the impact of treatment (antihypertensives ...) is surely necessary and has to take place within the frame of aviation medicine.
Frequently the orthopedic problems are of traumatic origin, and mainly vertebral. The effect of G acceleration and the risk of using the ejection seat are cause of restrictions.
The fact that oftalmological diseases only take the 3 rd place, is due to the severe recruiting standards to which all candidates should respond.
The different internal diseases, as described above influence by chronic evolution and treatment, the capacity of flying and so lead to specific restrictions.
Three out of four incapacity's of neurologic nature, are purely traumatically (long lasting coma) and caused by traffic accidents.
Although our pilots are subdued to an efficient psychological test and evaluation at selection, the individual assimilation of social problems or traumatic experiences remains being followed by

anxiety disorders. The psychological accompaniment of FP is a delicate problem and sometimes it is necessary to insure a further stability with restrictions.
The ENT problems that lead to restrictions, as in our 4 cases, mainly influences flight safety.
Analysis of disease development shows us that in 19% of the cases, predictive elements were there, some of them could have been detected by our actual selection system (spondiolysis, more restrictive norms for hypertension).
In other cases, diagnosis or final restriction were delayed by a chronically progression (32 %). It is discussible whether extended examinations would be of more profit. More important is an early detection, at the moment the risk for flight safety occurs or the health of the pilots demands treatment.
For the Commission, the question is always "Up to where can we go?". To the pilots, this question is " In which way can this pilot still fly?" in other words, under which restrictions can he continue flying?
As explained before, the Commission tries to declare - as specified, and detailed as possible- some times in consent with the commando, the restrictions under which a pilot is allowed to continue flying. In fig 4 these restrictions are shown.
The critical establishment is that the decision making of the Commission for one and the same disease is very often different. The reason therefor is individualization and the often exaggerated attention to fulfill the wish of the pilot involved. But in that way a straight line can't be kept, meaning that nor the members of the Commission, nor the pilots or the commando have a clear insight.
The members of the GCGLaf are aware of this, and one of the main reasons of this study was to look at this problem in a scientifically way to obtain a better view.
Although we studied only 43 pilots with restrictions, our results are interesting because they concern the total population of the BAF.
The diversity of diseases should lead us to more efficient screening examinations in order to obtain earlier detection and better preventive treatment.

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THE WAIVER PROCESS AND DISQUALIFYING MEDICAL CONDITIONS IN U. S. NAVAL AVIATION PERSONNEL

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1. SUMMARY

In the United States Navy, many diagnoses are considered disqualifying for aviation duty but may be "waived" to return to flight duties after resolution of the disease or appropriate treatment of the condition. Personnel with waivers are usually subject to more frequent physical examinations and/or special diagnostic procedures. Although the Naval Aerospace and Operational Medical Institute promulgates written aeromedical guidelines that delineate which disease conditions may be waived and which may not, waivers are granted on a case-by-case basis considering not only the diagnosis, but the age, experience, and type of aviation duty of the individual in question. This study was undertaken to determine which conditions were most and least likely to be waived. We reviewed all cases entered into the Naval Aviation Medical Data Bank who had been diagnosed with a condition considered disqualifying for aviation duty, totaling over 39,000 records. Cases were stratified by diagnosis and aviation duty and the percentage waived was calculated for major diagnostic groups. Approximately 66% of all cases with a disqualifying diagnosis were recommended for a waiver. Otolaryngologic, ophthalmologic and musculoskeletal disorders accounted for over 50% of diagnoses in personnel recommended for a waiver. Fear of flying, personality disorders and adjustment disorders were the three diagnoses least likely to be granted a waiver. The most common disqualifying diagnoses of aviation personnel not recommended for waiver were disorders of refraction and accommodation, obesity, allergic rhinitis, alcohol dependence, and hypertension. Designated aviation personnel were significantly more likely to be waived than students.

2. INTRODUCTION

The U.S. Navy's aeromedical service, the Naval Aerospace and Operational Medical Institute (NAMI), has the responsibility for evaluating aircrewmember's fitness to fly. The role of Naval Flight Surgeons, who are trained at NAMI, is to function as preventive medicine specialists and to detect and treat disease. In their preventive medicine role, flight surgeons perform periodic physical examinations on all aviation designated personnel. Subsequent to a physical examination, aircrewmembers are given an aeromedical disposition of physically qualified (PQ) or not physically qualified (NPQ) by the flight surgeon. As part of the flight physical, aircrewmembers are also evaluated for their ability to adapt to the rigors of aviation. This concept is known as aeronautical adaptability (AA).[1] To determine aeronautical adaptability, the flight surgeon evaluates the aircrewmember's attitude regarding Naval Aviation, motivation to fly, temperament, flexibility, and psychological defense mechanisms. A finding of not aeronautically adaptable (NAA) is generally considered permanently disqualifying. Aviation personnel who are found either NPQ or NAA are medically disqualified from further flight duties unless they are granted a waiver for their disqualifying condition.

The U.S. Navy Bureau of Medicine and Surgery (BUMED) publishes specific physical standards for all aviation duty categories. NAMI promulgates additional guidelines which delineate which disease conditions may be waived and under what circumstances. The Aeromedical Advisory Committee, a panel of aerospace medicine specialists at NAMI, regularly meets to review and update these physical standards and guidelines for the granting of waivers. Waivers are granted to aviation personnel on a case-by-case basis,

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as the physical requirements of each specific aviation duty and aircraft community differ. When a diagnosis or medical condition is considered to be disqualifying, but it can be determined that the individual's health, crew safety and mission completion would not be compromised, the granting of a waiver is considered. Further consideration is given to the age, experience level, and aircraft type flown by the disqualified individual. Waivers may be granted with specific restrictions, such as limitations to certain aircraft types and aviation duties.

All physical examination submissions and waiver requests for U.S. Navy aviation personnel are reviewed by the physical standards department of NAMI and then forwarded to the appropriate specialty consultative department for further review. The waiver evaluation process examines the aeromedical consequences of the disease and/or treatment, as well as the potential for disease recurrence, and correlates the results with knowledge of the associated stresses inherent to Naval Aviation. The physical standards department then makes a final decision, within current policy, to recommend or not recommend a waiver to return to flight status. The recommendation is then forwarded to U.S. Navy Bureau of Personnel for ultimate approval or disapproval. Those individuals granted a waiver are subject to increased medical scrutiny in the form of more frequent or more extensive aviation physical examinations than would otherwise be required. Personnel who are denied a waiver may appeal the decision via the Special Board of Flight Surgeons at NAMI.[1]

Since all aviation physical examinations are sent to a centralized location (NAMI) for review and processing, the opportunity to compile an extensive database on the aeromedical status of aviation personnel was apparent. At NAMI, the Aviation Medical Data Retrieval System (AMDRS) functions as an computerized repository of aeromedical data.[11] The AMDRS is an outgrowth of the U.S. Army Aeromedical Research Laboratory's Aviation Epidemiologic Data Register. The AMDRS was developed in 1989 and currently contains waiver data from 1986 to the present and physical examination submissions on all Naval Aviation personnel extending back to 1990. Physical examination data may be submitted from both local and remote sites, allowing timely entry of information from worldwide locations with central review and control of the database. The AMDRS has the potential to be utilized to perform epidemiological studies and to validate the standards and aeromedical dispositions of aviation personnel.

An analysis of the medical diseases and conditions considered disqualifying for U.S. Naval aviation has not been previously undertaken. Previous authors have examined medical disqualifications for the Royal Australian Air Force,[3] British military and civilian aviators,[1,12] Canadian Forces pilots,[14] French airline pilots,[7] U.S. civil airmen and airline pilots,[2,5] and U.S. Air Force aviation personnel.[6,9,13,15] The focus of these earlier studies was primarily on pilots and navigators, whereas the focus of this paper is on all aircrew, including pilots (hereafter referred to as Naval Aviators), flight officers, flight surgeons and enlisted aircrewmen. The AMDRS is representative of the Naval Aviation population, including aeromedical data on all of the above listed personnel types. The purpose of this report is to present the descriptive epidemiology of disqualifying medical conditions in U.S. Naval aviation personnel.

3. METHODS

The computerized database system (AMDRS) maintained by the Naval Aerospace and Operational Medical Institute was the source of all medical records used in this investigation. The waiver subsection of the AMDRS contains waiver request data on all aviation personnel who have been found not physically qualified or not aeronautically adapted on a standard flight physical examination. Subsequent physical examinations on an individual previously granted a waiver will also be recorded in the waiver subsection of the AMDRS. All waiver data entries contained in the database as of September 1993, totaling 39,098 records, were eligible for this study. A computer data file containing the aviation physical date, birth date, branch of service, type of physical examination, medical diagnoses (up to six), aviation duty, aeromedical disposition, total flight hours, and waiver status for each record was obtained.

These records represented the waiver request data of 20,352 separate individuals, with physical examination dates extending back into late 1986. These individuals had an average of 1.9 physical examinations recorded in the waiver database per person, with 40% of individuals having two or more waiver database entries. For individuals who had more than one waiver database entry, all entries were reviewed in their historical context. It was then determined whether the individual had received a waiver of the physical standards or not. In some cases, insufficient information was present in the database to make a determination of the present

waiver status; these 1,495 individuals were removed from the study population. 1,642 aviation personnel who had been found not physically qualified for a specific type of aviation duty but remained qualified for any other aviation duties (such as a Naval Aviator who has been assigned to a restricted flight status for aeromedical reasons) were also removed from the study population. The AMDRS also contains flight physical examination and waiver request data for a variety of personnel other than traditional aircrewmembers, such as all air traffic controllers, civilian support personnel, air-cushion landing craft operators, and NASA astronaut and mission specialist candidates. Records from 1,542 personnel belonging to these groups were excluded from the analysis in order to focus the study on aircrew personnel

For aviation personnel whose record entry included more than one diagnosis, the diagnosis judged to be most serious was chosen as the condition responsible for the disqualification A database containing all diagnoses listed in the International Classification of Diseases manual (ICD-9-CM) and a variety of military and aviation specific conditions, totaling over 18,000 entries, was reviewed independently of the study population and 16 major diagnostic categories were developed. The major diagnostic categories are listed in Table 1 An additional

TABLE 1. DIAGNOSTIC CATEGORIES

- Cardiovascular
- Dental
- Dermatology
- Endocrine / Metabolic
- Gastroenterology
- Genitourinary
- Hematology
- Infectious Diseases
- Miscellaneous
- Musculoskeletal
- Neoplasms
- Neurology
- Ophthalmology
- Otorhinolaryngology
- Psychiatry
- Pulmonary

category was developed to account for administrative disqualifications from aviation duties, such as substandard selection test scores, incomplete physical examinations, anthropometric incompatibilities, termination from aviation duties for administrative reasons, or voluntarily disenrollment from further aviation training. The 1,379 individuals who fell into this category were eliminated from the study because their disqualification was not due to an aeromedical decision, but instead were due to an administrative action. This selection process resulted in a final study group containing the records of 14,294 separate individuals which were subsequently analyzed.

Records were then categorized into two major groups, consisting of those who were recommended for a waiver of the applicable aeromedical standards (the "Waiver" group), and those who were not recommended for a waiver (the "No Waiver" group). Individuals in each of the two groups were then classified by diagnostic groups within each of the major diagnostic categories, by age, by primary aeronautical duty, and by branch of service. Age at the time of physical examination was used for this study. Comparisons of waiver frequencies among selected populations were made using Chi-square (X^2) tests for categorical variables and Student's t tests for continuous variables. Statistical significance was set at the 0.05 level, two sided

4. RESULTS

Table 2 presents the major demographic characteristics of the two groups within the study sample. Statistical comparison of the mean age, flight hours and diagnoses per physical is shown in Table 3. Of the 14,294 aviation personnel included in the study, 9,437 (66%) had been recommended for a waiver of their medical disqualification. As of 1 January 1994, the remaining 4,857 (34%) had not been recommended for a waiver. Aviation personnel who had been medically disqualified and not granted

TABLE 2. DEMOGRAPHIC CHARACTERISTICS OF NPQ & NAA NAVAL AVIATION PERSONNEL

	No Waiver Group	Waiver Group	Total
Number	4857	9437	14294
Diagnoses per physical	1 74	1.26	1.42
Mean age	30 0	32 1	31 4
Mean total flight hours	496.5	1048.5	861 0
USMC %	16.1	17 1	16 8
USN %	76 8	79.1	78 3
Naval Aviators %	19.9	33.6	29 0
Naval Flight Officers %	9.7	14 0	12.5
Naval Flight Surgeons %	0 8	2.5	1 9
Aircrew %	40.3	28 3	32 3
Designated %	70.8	78.4	75.8
Students %	29.2	21 6	24.2

TABLE 3. COMPARISON BY DIAGNOSES/ PHYSICAL, AGE AND TOTAL FLIGHT HOURS.

	Waiver	No Waiver	
	Mean (SEM)	Mean (SEM)	*p* value
Diagnoses/PE	1.3 (0.01)	1.7 (0.01)	<0.001
Age	32.1 (0.08)	30.0 (0.14)	<0.001
Flight Hours	1048.5 (15.6)	496.5 (17.4)	<0.001

a waiver were significantly more likely to have more diagnoses recorded at the time of their physical examination (1.7 diagnoses/physical) than those who were granted a waiver (1.3 diagnoses/ physical). In addition, medically disqualified personnel were of a younger average age and had less flight experience, and the difference was statistically significant. The proportion of Marine Corps to Navy personnel in the study groups was not significantly different.

Table 4 presents a listing of the primary disqualifying diagnoses classified by diagnostic groups within the major diagnostic categories for each of the two study groups and represents the basic data used throughout the rest of this paper. Diagnostic groupings were chosen to incorporate the diseases seen most frequently within a category. All diseases which occurred more than 10 times in the total study population were assigned to a specific diagnostic group. Diagnoses which were seen in less than 10 individuals were incorporated into the miscellaneous group of the appropriate diagnostic category. In addition, the proportions of personnel within the diagnostic groups who received a waiver were calculated. Based upon this data, the frequency distribution of personnel within each of the major categories was tabulated and is presented in Figure 1.

Ophthalmologic conditions accounted for the largest percentage of disqualifications in aviation personnel not recommended for a waiver, representing 14.8% of the total. Otolaryngologic diagnoses were responsible for next largest group of medical disqualifications, accounting for 12.8% of the total personnel not granted a waiver. Psychiatric conditions and other diagnoses (diseases not readily classified in any of the single organ system groupings) were the third and fourth most common conditions, each accounting for 11.8% of

FIGURE 1. DIAGNOSTIC CATEGORY DISTRIBUTION FOR WAIVER AND NO WAIVER GROUPS.

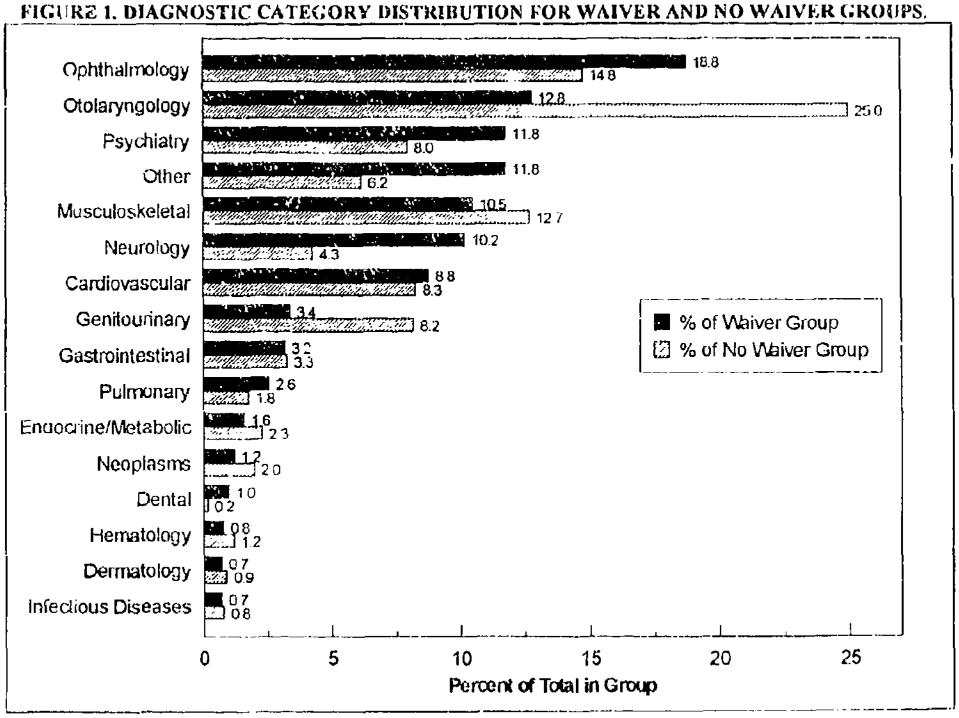

TABLE 4. CLASSIFICATION AND WAIVER PERCENTAGE FOR DIAGNOSTIC GROUPS.

Diagnostic Category	Diagnostic Groups	No Waiver Group	Waiver Group	Total	Percent Waived
Cardiovascular	Cardiomyopathy	4	7	11	63.6%
	Conduction Disturbances	10	11	21	52.4%
	Congenital Defect - Heart	15	17	32	53.1%
	Coronary Artery Disease	37	19	56	33.9%
	Dysrhythmias	98	112	210	53.3%
	Hypertension	156	426	582	73.2%
	Miscellaneous	28	17	45	37.8%
	Valvular Disease	67	141	208	67.8%
	Vascular Disease	13	33	46	71.7%
Dental		50	17	67	25.4%
Dermatology	Miscellaneous	21	36	57	63.2%
	Psoriasis	13	45	58	77.6%
Endocrine / Metabolic	Diabetes Mellitus	30	13	43	30.2%
	Gout	10	44	54	81.5%
	Lipid Disorders	12	47	59	79.7%
	Metabolic	7	9	16	56.3%
	Miscellaneous	8	7	15	46.7%
	Thyroid Disease	11	92	103	89.3%
Gastrointestinal	Esophageal Disease	16	51	67	76.1%
	Gastrointestinal Bleeding	7	29	36	80.6%
	Hepatitis	8	7	15	46.7%
	Hernia	36	3	39	7.7%
	Irritable Bowel Syndrome	7	11	18	61.1%
	Miscellaneous	29	36	65	55.4%
	Peptic Ulcer Disease	33	126	159	79.2%
	Ulcerative Colitis/Crohns Disease	17	49	66	74.2%
Genitourinary	Gynecology	2	12	14	85.7%
	Hematuria	13	65	78	83.3%
	Miscellaneous	18	28	46	60.9%
	Prostate Disease	8	8	16	50.0%
	Renal Disease	9	33	42	78.6%
	Urolithiasis	115	624	739	84.4%
Hematology	Anemia	22	50	72	69.4%
	Hemoglobinopathies	7	34	41	82.9%
	Miscellaneous	6	9	15	60.0%
	Status Post Splenectomy	1	14	15	93.3%
	Thrombocytopenia	4	6	10	60.0%
Infectious Diseases	Fungal Disease	7	46	53	86.8%
	Herpetic Infections	6	20	26	76.9%
	HIV Infection	13	1	14	7.1%
	Miscellaneous	9	12	21	57.1%
Musculoskeletal	Arthropathies	56	68	124	54.8%
	Disorders of the Spine	32	90	122	73.8%
	Herniated Nucleus Pulposis	110	377	487	77.4%
	Knee Disorders	106	273	379	72.0%
	Limb Fractures / Dislocations	55	62	117	53.0%
	Low Back Pain	38	9	47	19.1%
	Miscellaneous	40	60	100	60.0%
	Retained Orthopedic Hardware	11	161	172	93.6%
	Shoulder Disorders	33	87	120	72.5%
	Soft Tissue Injuries	31	25	56	44.6%
Neoplasms	Dermatology	6	65	71	91.5%
	Gastrointestinal	8	7	15	46.7%
	Genitourinary	14	40	54	74.1%
	Hematologic	13	28	41	68.3%
	Miscellaneous	13	42	55	76.4%
	Central Nervous System	6	6	12	50.0%

TABLE 4. (CONTINUED)
CLASSIFICATION AND WAIVER PERCENTAGE FOR DIAGNOSTIC GROUPS.

Diagnostic Category	Diagnostic Groups	No Waiver Group	Waiver Group	Total	Percent Waived
Neurology	Air / Motion Sickness	123	16	139	11.5%
	Cerebrovascular Disease	3	8	11	72.7%
	Decompression Sickness	31	67	98	68.4%
	Demyelinating Diseases	6	5	11	45.5%
	Infection	5	6	11	54.5%
	Intracranial Injury	54	82	136	60.3%
	Loss of Consciousness	27	26	53	49.1%
	Migraine / Headache	155	146	301	48.5%
	Miscellaneous	20	20	40	50.0%
	Peripheral Nerve Disease	14	19	33	57.6%
	Seizure Disorder	52	4	56	7.1%
	Spinal Cord Disorder	5	10	15	66.7%
Ophthalmology	Cataract	13	44	57	77.2%
	Color Vision Deficiency	79	82	161	50.9%
	Corneal Disorder	23	36	59	61.0%
	Defective Stereopsis	54	40	94	42.6%
	Extraocular Motility Disorder	18	30	48	62.5%
	Glaucoma	17	58	75	77.3%
	Iris Disorder	4	14	18	77.8%
	Miscellaneous	8	20	28	71.4%
	Refraction / Accommodation Disorders	678	1006	1684	59.7%
	Retinal Disease	18	64	82	78.0%
Other	Allergy / Anaphylaxis	10	15	25	60.0%
	Barotrauma	8	4	12	33.3%
	Heat Exhaustion / Heat Stroke	3	3	6	50.0%
	Hymenoptera Sting Allergy	20	53	73	72.6%
	Medication Use	21	56	77	72.7%
	Miscellaneous	28	20	48	41.7%
	Obesity	483	436	919	47.4%
Otolaryngology	Allergic Rhinitis	291	1844	2135	86.4%
	Cholesteatoma	4	20	24	83.3%
	Eustachian Tube Dysfunction	113	12	125	9.6%
	Hearing Loss	58	244	302	80.8%
	Inner Ear Disease	12	19	31	61.3%
	Miscellaneous	23	67	90	74.4%
	Nasal Polyps	14	29	43	67.4%
	Otitis Media / Externa	7	12	19	63.2%
	Sinus Disease	99	114	213	53.5%
Psychiatry	Adjustment Disorders	56	3	59	5.1%
	Alcohol Dependence/Abuse	171	470	641	73.3%
	Anxiety Disorders	49	6	55	10.9%
	Depressive Disorders	43	26	69	37.7%
	Eating Disorders	6	4	10	40.0%
	Fear of Flying / Loss of Motivation	28	0	28	0.0%
	Learning Disorders	10	1	11	9.1%
	Miscellaneous	44	8	52	15.4%
	Other Substance Dependence / Abuse	40	222	262	84.7%
	Personality Disorders/Traits	81	1	82	1.2%
	Phobias	35	4	39	10.3%
	Somnambulism	10	6	16	37.5%
Pulmonary	Asthma	70	55	125	44.0%
	COPD	4	16	20	80.0%
	Miscellaneous	34	29	63	46.0%
	Pneumothorax	11	46	57	80.7%
	Sarcoidosis	9	22	31	71.0%
Total		4857	9437	14294	66.0%

disqualifications. In contrast to the non-waived group, the most frequent conditions recommended for waiver were otolaryngologic, ophthalmologic and musculoskeletal diseases, representing 25.0%, 14.8%, and 12.7% respectively. These three disease categories accounted for over one-half of all conditions recommended for a waiver.

TABLE 5. DIAGNOSTIC CATEGORIES BY AGE GROUPS.

Diagnostic Category	17-29	30-39	40+	Total
Cardiovascular	317	410	484	1211
Dental	31	18	18	67
Dermatology	53	35	27	115
Endocrine / Metabolic	53	92	145	290
Gastrointestinal	137	167	161	465
Genitourinary	283	367	285	935
Hematology	75	42	36	153
Infectious Diseases	55	45	14	114
Musculoskeletal	747	559	418	1724
Neoplasms	42	98	108	248
Neurology	511	251	142	904
Ophthalmology	1433	489	384	2306
Other	560	365	235	1160
Otolaryngology	2018	640	324	2982
Psychiatry	777	407	140	1324
Pulmonary	137	87	72	296
Totals	**7229**	**40[illegible]**	**2993**	**14294**

Table 5 presents the age group breakdown of the total study population within each diagnostic category. The age distribution of the entire study population is skewed towards the 17-29 year old age group, which mirrors the general age distribution of the active duty population. In general, the age distribution of each diagnostic category parallels the age distribution of the study population, with the exception of cardiovascular, endocrine/metabolic disorders, and neoplastic diseases. This is not unexpected considering that coronary artery disease, hypertension, diabetes, lipid disorders and malignancies are more prevalent in older age groups. The 40+ age group represents 21% of the total study population and accounted for 20% of personnel denied a waiver. This was in marked contrast to the study of USAF medical disqualifications by Whitton, in which the over 40 age group accounted for 55% of disqualifications.[15] It is hypothesized that this difference is due to a difference in study populations; Whitton studied only designated pilots and navigators while this study includes a large proportion of younger enlisted aircrewmen and student aviation personnel.

TABLE 6. DIAGNOSTIC GROUPS MOST LIKELY TO BE WAIVED.

Diagnostic Group	Percent Waived
Retained Orthopedic Hardware	93.6%
Status Post Splenectomy	93.3%
Dermatologic Neoplasms	91.5%
Thyroid Disease	89.3%
Fungal Disease	86.8%

The diagnostic groups most and least likely to be waived were extracted from Table 4, rank-ordered and are presented in Tables 6 and 7 respectively.

Retained orthopedic hardware was the condition most likely to be waived, being waived in almost 94% of the 172 personnel with the condition. Current U.S. Navy aeromedical standards stipulate that retained hardware is disqualifying, but a waiver is easily granted if the orthopedic injury is healed and there is no impairment of mobility. Splenectomized individuals and dermatologic neoplasms were the second and third most frequently waived conditions, being waived 93.3% and 91.5% of the time respectively.

TABLE 7. DIAGNOSTIC GROUPS LEAST LIKELY TO BE WAIVED.

Diagnostic Group	Percent Waived
Fear of Flying / Loss of Motivation	0.0%
Personality Disorders/Traits	1.2%
Adjustment Disorder	5.1%
Seizure Disorder	7.1%
HIV Disease	7.1%

Fear of flying or loss of motivation to fly is universally acknowledged as being incompatible with further aviation service and was the condition least likely to be waived, with no waivers granted among the 28 personnel with this condition. The psychiatric conditions of personality disorders/traits and adjustment disorders were the next least likely groups to be waived, being waived only 1.2% and 5.1% of the time respectively. In general, individual with these conditions are not suitable for continued military service and are only rarely waived to remain in flight status.

An unexpected finding was that seizure disorders and HIV infection were waived in rare cases. These waived cases were then individually reviewed. The four cases of seizure disorder were waived for a single seizure due to some temporary or reversible

environmental cause. The one waiver granted to an HIV infected aviator was not due to a recommendation for waiver approval by NAMI, but was the result of an appeal to a higher non-medical authority.

From Table 4, the diagnostic groups most likely to have waivers recommended and not recommended, respectively, were extracted and rank-ordered and are presented as Tables 8 and 9.

TABLE 8. MOST FREQUENT DIAGNOSTIC GROUPS RECOMMENDED FOR WAIVER.

Diagnostic Group	Number of Diagnoses
Allergic rhinitis	1844
Disorders of refraction / accommodation	1006
Urolithiasis	624
Alcohol dependence / abuse	470
Obesity (weight exceeding standards)	436

Refractive and accommodative errors were noted to be both the most frequently occurring diagnostic group not recommended for a waiver and the second most frequent group recommended for a waiver. This is in line with the strict vision standards for aviation personnel and the need for close follow-up of individuals who fall outside of the standards and are eligible for waiver. In general, designated personnel with refractive errors are frequently granted a waiver while aviation candidates and student aviators are less likely to be waived.

TABLE 9. MOST FREQUENT DIAGNOSTIC GROUPS NOT RECOMMENDED FOR WAIVER.

Diagnostic Group	Number of Diagnoses
Disorders of refraction / accommodation	678
Obesity	483
Allergic rhinitis	291
Alcohol dependence / abuse	171
Hypertension	156

Obesity was the second most frequently occurring diagnostic group for individuals not granted a waiver and the fifth most frequent diagnosis in waived individuals. This apparent dichotomy can be explained by an understanding of individual diagnoses contained within this group. The diagnostic group of obesity includes the diagnoses of not only obesity, but also of weight exceeding aviation and/or military standards. Individuals who exceed weight standards can be waived if they otherwise maintain an acceptable body physique, are in good physical condition, and their weight and size does not compromise aviation safety.[8]

Allergic rhinitis was the most frequent diagnosis among personnel granted a waiver, the third most frequently occurring for those not recommended a waiver, and the most frequently occurring diagnostic group overall. Allergic rhinitis is a common disorder that is potentially disruptive to aviation duty if the condition occurs frequently or for prolonged periods of time. The diagnosis or history of allergic rhinitis after age 12 is considered disqualifying in all aviation personnel, but is readily waived for individuals who are minimally symptomatic or asymptomatic. The existing NAMI criteria for establishing the diagnosis are currently under review to determine if a more relaxed standard, which would result in less disqualifications, would be appropriate.

A history of alcohol dependence or abuse was the fourth most frequent diagnostic group for personnel both granted a waiver and those not recommended for waiver. As in the general population, this condition is common. Diagnosed aviation personnel who successfully complete a prescribed treatment program may be granted a waiver subject to close aeromedical monitoring.

Hypertensive disease was the fifth most common diagnosis among individuals not recommended for a waiver. In addition to the disease itself, medications used to treat this disorder are disqualifying for aviation duty due to the possibility of adverse reactions or undesirable side effects. Treated individuals who are normotensive and on a stable dose of an approved medication may be granted a waiver to return to flight duties.

Urolithiasis was the third most common diagnosis among aviation personnel granted a waiver. Recurrent renal and ureteral calculi are a potential cause of inflight incapacitation among susceptible individuals. Aircrew who have had an initial episode of urolithiasis require a thorough metabolic evaluation prior to being granted a waiver to return to flight duties.

Table 10 shows the study groups classified according to their primary aviation duty. A comparison of the waiver rates for designated and student (non-

TABLE 10. AVIATION DUTY CLASSIFICATION.

	DESIGNATED				STUDENTS			
Group	AC	NA	NFO	NFS	SNA	SNFO	SNFS	Total
No Waiver	1956	968	473	41	992	385	42	4857
Waiver	2668	3173	1320	234	1461	380	201	9437
Percent waived	57.7	76.6	73.6	85.1	59.6	49.7	82.7	66.0
Total	4624	4141	1793	275	2453	765	243	14294

AC = Aircrewman, NA = Naval Aviator, NFO = Naval Flight Officer, NFS = Naval Flight Surgeon,
SNA = Student Naval Aviator, SNFO = Student Naval Flight Officer, SNFS = Student Naval Flight Surgeon.

designated) aviation personnel was performed and is presented in Table 11.

TABLE 11. COMPARISON OF WAIVER FREQUENCY FOR DESIGNATED VS. STUDENT GROUPS

Group	Waiver	No Waiver	Percent Waived
Designated	7395	3438	68.3
Students	2042	1419	59.0

OR = 1.49, 95% CI = 1.39 to 1.61, $p < 0.001$ two sided

Designated personnel, as a group, were significantly more likely to be waived than students (OR = 1.49). This is consistent with current waiver guidelines which reflect the aeromedical philosophy of being willing to accept more risk of disease in trained and experienced aviation personnel.

Bi-variate analyses of the differences in waiver rates between the various specific aviation duty groups were performed and the results are shown in Table 12. Odds ratios (OR) are reported for each comparison.

Significant differences were noted between all primary aviation duty groups analyzed. As a group, Naval Aviators were more likely to be granted waivers than Naval Flight Officers (OR = 1.18) and Naval Aircrewmen (OR = 2.38). Naval Flight Officers were also more likely to be waived than aircrewmen (OR = 2.04). Naval Flight Surgeons were significantly more likely to be granted waivers than any other group, including Naval Aviators (OR = 1.75), Naval Flight Officers (OR = 2.04), and aircrewmen (OR = 4.17).

Although these differences in waiver rates for selected aviation duty groups were shown to be statistically significant, it might be more useful to look at the difference in waiver rates for specific diagnoses amongst the various groups.

Limitations of this study included a number of incomplete records in the initial study population. Many of these incomplete database entries were due to

TABLE 12. WAIVER STATUS FOR SELECTED AVIATION DUTY GROUPS.

Group	Waiver	No Waiver	OR (95% CI)	p value
NA	3173	968	1.18 (1.03-1.33)	0.013
NFO	1320	473		
NA	3173	968	2.38 (2.17-2.63)	< 0.001
AC	2668	1956		
NA	3173	968	0.57 (0.40-0.81)	< 0.001
NFS	234	41		
NA	3173	968	1.92 (1.75-2.08)	< 0.001
All Other	4222	2470		
NFO	1320	473	2.04 (1.82-2.33)	< 0.001
AC	2668	1956		
NFO	1320	473	0.49 (0.34-0.70)	< 0.001
NFS	234	41		

the fact that complete physical examination data was not entered on all individuals until 1990; records from 1987 to 1990 included only specific waiver information and were missing general demographic data. These limitations were accounted for in analyzing the data, where out of 20,352 individuals in the waiver file, 1,495 (7.4%) were discarded due to incomplete records. It is unknown what effect this may have had on the results. Since the database only includes aviation physical examination data, it is possible that aviation personnel with severe or disabling medical conditions who are immediately removed from flight status will not have a final aviation physical submitted to the database. This would lead to systematic underreporting of serious disease within all aviation categories. A substantial proportion of individuals who were only recently reported to have a disqualifying condition and were not granted a waiver may yet be granted a waiver, allowing for resolution of their disease, completion of treatment, or administrative delays in the processing of their waiver requests.

Due to the unavailability of population statistics for aviation duty groups at the time of this study, actual prevalence and incidence rates were unable to be calculated. This data should be obtainable from other sources and will be reported in future studies.

5. CONCLUSION

Although other military services have previously reported on medical disqualifications in aviation personnel, this is the first study to analyze and report on the waiver data contained in the U.S. Navy's Aviation Medical Data Retrieval System. In addition, this study is unique for the inclusion of enlisted aircrewmen data in the analysis of medically disqualifying conditions.

The information obtained in this study is useful in reviewing the medical standards for disposition of designated aviation personnel and for selection of aviation candidates. The development of selection criteria, physical standards, and preventive medicine programs can be based on information gleaned from the database. The database serves as an efficient epidemiological tool to assist in aeromedical decision making.

The waiver process provides a method for minimizing losses of trained aviation personnel. The economic and manpower issues of losing trained personnel are weighed against the safety and mission requirements of the U.S. Navy and Marine Corps. Waiver recommendations are evaluated in the context of Naval Aviation as a whole, thereby not losing either the individual or corporate perspective. The old adage of "keep 'em flying safely" continues to shine through aerospace medicine in the U.S Navy and Marine Corps

6. ACKNOWLEDGMENTS

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The views and opinions contained in this report are those of the authors and should not be construed as official policies of the Bureau of Medicine and Surgery, the Department of the Navy, or the Department of Defense.

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THE EFFECT OF SPECIAL BOARDS OF FLIGHT SURGEONS ON THE EVOLUTION OF U. S. NAVAL FLIGHT STANDARDS

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INTRODUCTION

The flight surgeon is frequently asked to make a determination on the "fitness to fly" of a member of his or her squadron. Common medical conditions that are transient, unlikely to progress in the operational environment, and have no sequelae that could compromise safety of flight do not result in the physical disqualification of the aviator. These simple cases lend themselves to a prompt aeromedical disposition and are routinely handled by the squadron flight surgeon through the issuance of temporary grounding notices. Following resolution of the acute illness, the aviator can immediately return to full flight status. If any of these prerequisites are not met, however, the aeromedical disposition becomes more complex. Medical conditions that may have significant sequelae, require long term follow up, or those that require chronic medication are not compatible with existing Naval aviation physical standards. If the aviator's career is to be preserved, a waiver of physical standards must be obtained. These challenging cases are generally handled by the squadron flight surgeon, with input from higher medical authorities. These recommendations are forwarded to the Bureau of Personnel for final action. The line community is the final arbiter of standards, and will issue a waiver for flight status based on the needs of the service.

Since 1956, the U.S. Navy aeromedical community has officially recognized the need for an approach to evaluate aviators with significant fitness for flight questions (1). In 1957, the Chief of Naval Air Training established a reviewing body of specialty trained flight surgeons at the Naval Aviation Medical Center in Pensacola, Florida. This group became known as the Special Board of Flight Surgeons. Initially, the board was tasked with serving the aviation training command and evaluated student aviators who were found to have physical or emotional factors affecting their training. Gradually, the numbers of individuals referred from fleet squadrons increased; currently, any Navy or Marine Corps squadron can refer aviation officers (pilots, flight officers, flight surgeons, aerospace physiologists, aerospace experimental psychologists) to a Special Board of Flight Surgeons for examination and aeromedical recommendations. Few students are currently referred to Special Boards. An independent body of senior flight surgeons assigned to the Bureau of Medicine can also be called upon to render aeromedical opinions in certain cases. The Senior Board of Flight Surgeons can make recommendations that supersede the recommendations of the Special Board of Flight Surgeons, and in effect can serve as the court of last resort for aviators seeking another hearing of their case prior to final recommendation.

A Special Board of Flight Surgeons is requested by an aviator's commanding officer. Medical information is supplied to the clinical departments at the Naval Aerospace and Operational Medical Institute (NAMI) and a recommendation on the merits of hearing the case is then made to the commanding officer of NAMI. Should the commanding officer desire, the board is convened and the aviator is ordered to NAMI for evaluation. A disqualifying condition considered by the board must be resolved or stable. The aviator undergoes a comprehensive examination during the week prior to the board by each clinical department at NAMI. During the course of the board, the case is presented and the aviator has the chance to present additional information in his behalf. The hearing is then closed and the aviator excused. At this point, the clinical department primarily responsible for the case presents a formal "Grand Rounds" type of presentation with didactic lecture, pertinent educational materials and a review of the literature. The case is discussed, with particular emphasis on aeromedical and operational concerns. The members of the board vote on recommendations for continued flight status. The findings of the board are summarized and documented in a standard format. This format includes a rationale explaining the recommendations of the board. The board's recommendations are forwarded to the Bureau of Personnel for final disposition.

Several possible recommendations can result from a special board proceeding. An aviator may be recommended for return to unrestricted flight status. In the U.S. Navy classification for pilots, this is Class I, Service Group 1. These aviators are able to fly any aircraft in which they are qualified, and includes aircraft carrier operations. Failing this, an aviator may be recommended for either Service Group 2 or 3. Service Group 2 status permits aviators to fly any aircraft in which they are qualified, but precludes operation on aircraft carriers. Helicopter pilots in Service Group 2 may still, however, fly on and off aircraft carriers. Service Group 3 aviators can fly only in dual controlled aircraft with a Service Group 1 or 2 aviator at the other set of controls. Naval Flight Officers (bombardier/navigators, radar intercept officers, electronic countermeasure officers) and other aircrew not in actual control of the aircraft (enlisted flight engineers, flight surgeons, aerospace physiologists, etc.) are Class II personnel. An aviator may be recommended for temporary removal from flight status, with an outline for repeat evaluation in the future. Finally, an aviator may be recommended for permanent grounding.

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The nature of special board cases has been reviewed extensively in the past. Proceedings of the early boards were described in 1958 and 1960 (1,2). A review of the psychiatry Special Boards was presenteded in 1967 (3). The first comprehensive review (4,5) was published in 1972, and examined the first 13 years of the special board program. A total of 720 presentations for 580 designated aviators were evaluated over this period. Some aviators were evaluated on more than one occasion. The total number of hearings was used as the denominator, as each hearing had the potential for a different recommendation and outcome. Of the 720 cases, 283 (39.3%) received a recommendation for return to Service Group 1. A Service Group 2 recommendation resulted in 43 cases (6.0%) and a Service Group 3 recommendation in 173 (24.0%). Twenty-eight aviators (3.9%) were temporarily grounded, and 179 (24.9%) were permanently grounded. Cardiovascular causes were the most common reason for referral to the board, accounting for 42% of cases.

Alcoholism was an uncommon diagnosis, accounting for only eight of the cases heard before a special board. Of this group, five (62.5%) were permanently grounded. Eleven cases of migraine headache were presented before a special board. None of these aviators were permanently grounded, and all were returned to flight status in either Service Group 1, 2 or 3.

The special board process was again reviewed in 1986 (6). This publication examined the cases from 1974 to 1983. Some data were unavailable at the time of publication, hence only 85% (n=248) of the potential cases were analyzed. In contrast to the earlier study group, neurologic diagnoses accounted for the greatest number of referrals, comprising 24.0% of the total cases heard. Psychiatric diagnoses were the next largest subgroup, comprising 21.1% of the referrals. Cardiovascular cases were third, with 14.9% of the referrals. The remaining cases were relatively evenly divided between ophthalmology, otorhinolaryngology, general internal medicine and orthopedics. The authors concluded that advancing age was correlated with recommendations for more restrictive flight status. Similarly, younger aviators were returned to unrestricted flight status more often than older aviators, but these observations were probably an artifact of a prior Navy policy. Before 1980, a pilot was automatically placed into Service Group 3 upon reaching 45 years of age. The study period included a time when this policy was in force, thereby making it impossible to recommend anything other than Service Group 3 for the senior aviators seen before a Special Board. Otorhinolaryngologic and ophthalmologic referral diagnoses were less likely to be returned to flight status. Neurologic and psychiatric diagnoses were also less likely to be returned to full flight status.

METHODS

All special board cases presented at NAMI from 1 January 1984 until 31 December 1993 were reviewed. There were 119 special board cases involving 116 individuals. Three individuals appeared before the board on two separate occasions. Pertinent demographic data were entered into a computerized database program (dBase III, Ashton-Tate Inc.) for trend analysis. The rationale for the aeromedical conclusions reached in each of the 119 cases presented in the past ten years was explored in detail. No statistical analyses were attempted on the data. The effect of sex and race on board outcome were considered, however, there were only two females and few minorities during the time frame considered negating any statistical significance.

RESULTS

Of the 119 cases, 105 were held for naval aviators. Nine aviators (8.5%) were found to be physically qualified for duties involving flight. The remaining 96 were found not physically qualified, but waivers were recommended for all but 28 (26.7%). Of the 68 aviators who had wavers

Table 1. SBFS Diagnoses

1. Migraine Headache	11
2. Loss of Consciousness/Syncope	10
3. Closed Head Injury	7
4. Supraventricular Tachycardia	6
5. Cerebrovascular Accident	5
6. Malignancy	5
7. Seizure	4
8. Spinal Cord Injury	4
9. Vertigo/Disequilibrium	4
10. Occupational Problems	3
11. Adjustment Disorder	3
12. Anorexia/Bulimia	3
13. Human Immunodeficiency Virus	3
14. Atrial Fibrillation/Flutter	3
15. Coronary Artery Disease	3
16. Optic Neuropathy/Neuritis	3
17. Inflammatory Bowel Disease	3
18. Personality Disorder	2
19. IgA Nephropathy	2
20. Cataract Removal with Lens Implant	2
21. Central Nervous System Infection	2
22. Reactive Psychosis	1
23. Macular Degeneration	1
24. Pulmonary Alveolar Proteinosis	1
25. Central Scotoma	1
26. Pulmonary Edema	1
27. Exotropia	1
28. Sarcoidosis	1
29. Pneumonia	1
30. Cardiomyopathy	1
31. Joint Trauma	1
32. Psoriasis	1
33. Scoliosis	1
34. Gastrointestinal Hemorrhage	1
35. Internuclear Ophthalmoplegia	1
36. Cervical Dystonia	1
37. Hypothalamic Tumor	1
38. Cerebellar Hemangioma	1
39. Delirium	1
40. Dissociative Symptoms	1
41. Asthma	1
42. Beta Thalassemia	1
43. Thrombotic Thrombocytopenic Purpura	1
44. Agoraphobia	1
45. Primary Adrenal Insufficiency	1
46. Hip Arthroplasty	1
47. Decompression Sickness (recurrent)	1
48. Altered Level of Consciousness	1
49. Diverticulitis	1
50. Reconstructive Surgery of the Hand	1
51. Insufficient sitting/reaching height	1
52. Wegener's Granulomatosis	1

recommended, twenty eight (26.7%) aviators were returned to Service Group 1 duties, ten (9.5%) were returned to Service Group 2 duties and 30 (28.6%) were returned to Service Group 3 status. Of the class II individuals waiver of flight standards was recommended in 12 (85.7%) and no waiver in 2 (14.3%). The diagnoses evaluated by the board are summarized in table 1.

The effect of age on waiver outcome is summarized in table 2. There does not appear to be an effect of advancing age decreasing the likelihood of waiver. There is still a tendency to recommend a waiver to Service Group III in aviators over the age of. 40.

Table 2. Waiver Status by Age Group

Age	Waiver Recommended		Waiver Not Recommended		Service Group 1	2	3
20-24	2	(66%)	1	(34%)	1	1	
25-29	14	(56%)	11	(44%)	8	1	4
30-34	19	(73%)	7	(27%)	11	2	5
35-39	25	(93%)	2	(7%)	8	5	7
40-44	15	(79%)	4	(21%)	4		8
45-49	8	(80%)	2	(20%)	3	1	4
50+	1	(50%)	1	(50%)	1		1

The aviators rank did not seem to effect board outcome. Except for the rank of O-2, the majority of aviators received a waiver regardless of rank. This data is summarized in table 3.

Table 3. Waiver Status by Rank

Rank	Waived		Not waived	
O-1	2	(66%)	1	(34%)
O-2	4	(44%)	5	(56%)
O-3	28	(70%)	12	(30%)
O-4	26	(89%)	3	(11%)
O-5	19	(79%)	5	(21%)
O-6	7	(78%)	2	(22%)
O-7	1			

The trends in the diagnostic category of cases referred has also changed. From 1957-1973, cardiology cases accounted for the primary referral diagnosis. From 1974-1983, neurologic diagnoses were the primary referring diagnosis. This trend continued in the present series and is summarized in table 4.

Table 4. Diagnostic Categories

	Number	Percent
Neurology	52	43.7
Cardiology	16	13.4
Psychiatry	14	11.8
Ophthalmology	8	6.7
Gastroenterology	5	4.2
Pulmonary	5	4.2
Orthopedics	5	4.2
Oncology	5	4.2
Infectious Disease	3	2.5
Nephrology	2	1.7
Hematology	2	1.7
Dermatology	1	0.8
Endocrinology	1	0.8
Total	119	100

Neurologic diagnoses accounted for 52 of the 119 special board cases (43.7%). Migraine headache was the most frequent reason for referral overall, and resulted in 11 of the 52 neurologic cases (21.2%) referred to special board. Interestingly, the aeromedical disposition of migraineurs seen by the special board did not vary between the earliest series and the present series.

DISCUSSION

No cases of alcoholism were evaluated before special boards from 1984-1993. This reflects a standardization of the waiver process for this condition. Alcoholism in remission is currently covered by a Bureau of Medicine instruction that details conditions that must be met before a waiver recommendation will be made, and the follow on care necessary for the waiver to be continued. These cases are now handled at the level of the squadron flight surgeon under the disposition guidelines delineated in the instruction.

Cases of atrial fibrillation/flutter were once routinely heard before special boards. In this case, the special board proceedings have had the effect of revising policy. Guidelines for the evaluation and serial observation of patients with atrial dysrhythmia grew out of special board presentations. These recommendations were standardized at NAMI and approved by the Bureau of Medicine. The end result is that atrial dysrhythmia is handled by the squadron flight surgeon and the internal medicine department at NAMI. The requirement for the aviator to appear before a special board has been eliminated in the vast majority of cases.

The disposition of supraventricular tachycardia (SVT) has undergone significant revision since the board's inception. Prior to the 1980's, there was no aeromedically appropriate means to treat symptomatic SVT. Long term pharmacotherapy was unacceptable for flight status, and surgical or direct current (DC) ablation posed the risk of significant side effects. With the advent of radiofrequency (RF) catheter ablation coupled with electrophysiologic study (EPS) mapping of the cardiac conduction system, the possibility exists for the relatively atraumatic cure of the underlying condition. One case of catheter ablation of an accessory conduction pathway has been heard before the special board, with the recommendation that the aviator be returned to flight status. This case has also prompted a review of the existing aeromedical policy regarding the ablation of aberrant conduction pathways. New recommendations have been [illegible]de to the Bureau of Medicine regarding the use of this t[illegible]que in aviators with symptomatic SVT.

The increased utilization of advanced technology has directly impacted the cases heard before special boards. In one case of a transient ischemic attack, magnetic resonance imaging of the brain documented a small lesion in the caudate area of the cerebral cortex that was not seen on either routine or

contrast enhanced CT scans of the head. The location of the infarct was entirely consistent with the aviator's symptoms. Color flow Doppler echocardiography coupled with bubble contrast echocardiography documented the presence of an atrial septal aneurysm and associated atrial septal defect in this aviator. Following repair of the cardiac abnormality, the aviator was seen before a special board. The discussion in this case centered on the potential for the old area of ischemia to serve as a focus for epileptic activity, and the consequences of the cardiac repair in the operational environment. Once it was determined that the infarct area was not likely to serve as an epileptogenic focus, and no cardiac complications could be demonstrated by repeat bubble contrast echocardiography and serial Holter monitoring, the aviator received a recommendation for return to flight status.

The rationale used by the board to recommend or not recommend a waiver was analyzed. Numerous recurrent themes and criteria were noted. The factors considered and used as a basis for the aeromedical decision making process were analyzed and summarized in the following paragraphs.

The natural history of the disease, long term survival, and duration of symptom free interval were primary factors considered. Risk of future disease recurrence and predisposition to develop other problems (epilepsy following cerebral trauma or cardiac arrhythmias following cardiac disease) were important criteria. Does the past course of the disease predict the future course of the disease? This factor was considered in a patient with Crohn's disease and several neurologic cases, mild forms of disease with minimal symptoms were predicted to stay that way. With injuries, especially neurologic and orthopedic injury the predisposition for recurrent injury and degree of residual impairment was important.

A major concern was whether the disease process posed any risk or potential for sudden in flight incapacitation or the possibility for incapacitation in a hazardous situation. Also, is there any risk for subtle incapacitation which might not be detected by the individual but would affect his mental judgement and physical abilities to control the aircraft. These factors were important in a whole array of neurologic, cardiologic and endocrine disease states considered.

Aeromedical safety was a recurrent theme. What is the impact of the disqualifying defect on aviation safety? The safety of the crew as well as that of the patient were considered. The effects on communication and air crew coordination were considered.

With military aviation, the board needed to be cognizant of whether the disease process would affect operational effectiveness and mission completion. The patient must remain as a readily deployable asset. Each aircraft-aircraft mission had to be considered. The effect of the disease state on exercise tolerance, fatigue, and circadian rhythms was taken into account. This was the primary disqualifying rationale in permanently grounding a superb jet aviator with Addison's disease (primary adrenal insufficiency).

The effect of the aviation environment on the disqualifying condition was explored. The individual must be able to adapt to the aviation environment, especially the military flight environment. The effect of G forces on cardiac arrhythmias is a well known fact. The effect of oxygen/hypoxia on the numerous pulmonary cases was considered and if a waiver was granted, the aircraft was often specified so that the aviator would not be exposed to ranges of oxygen tension. In patients with neurologic or orthopedic deficits the forces of ejection were of prime importance. Will the aviator still be able to safely egress from a disabled aircraft?

The treatment required for the patient's medical condition must be readily available. Naval aviators are deployed throughout the world, often in hostile environments. For certain diagnoses considered by the board, there was a need for special treatment or care. Can the condition be effectively treated and cared for in the operational environment? Is there adequate medical care in areas of deployment and deployment platforms? The possibility of capture of the aviator was considered; would he be able to survive if captured, is there a need for an uninterrupted supply of medication? In any medical conditions requiring a medication, the safety profile of the medication and medication side effect profile were carefully scrutinized.

At times, the board utilized a statistical approach to resolve complex cases. Decision making and risk assessment principles were used. They employed decision analysis techniques using decision analysis models and probability models for prediction. What is the most likely scenario versus the worst case scenario? The board examined the relative risks and benefits; the risk of adverse impact on safety, and of mission compromise. This approach to aeromedical decision making was presented recently in an article by JB Clark.(7)

Cases of senior aviators with significant medical conditions were often difficult cases for the Board to deliberate. The issues of career preservation, conservation of human resources, and cockpit resource management were considered and contrasted with the expected evolution of the senior officer from a line pilot to administrator and teacher.

CONCLUSIONS

Since their inception, Special Boards of Flight Surgeons have undergone significant transformation in both the number and nature of cases evaluated. The number of cases has decreased since the board began providing aeromedical dispositions. In the first year of operation, the Special Board evaluated 11 designated aviators, and reached a peak of 71 evaluations in 1962.

While they are not intended as a policy setting instrument, some rulings have had the effect of revising aeromedical policy. Special Board opinions have been used as calls for the review of existing aeromedical policy regarding some conditions. In some cases policy changes have resulted when all available evidence was reviewed and presented to NAMI and the Bureau of Medicine. When enacted by the Chief of Naval Operations, these policy changes have generally had the effect of liberalizing physical standards. This liberalization has enabled the squadron flight surgeon to

provide an aeromedical disposition without referring the individual to a Special Board.

The patient population referred to the Board has also dramatically changed. Several factors are no doubt responsible for the shift in referral pattern. Student Naval aviators are rarely referred to Special Boards now, but comprised a significant fraction of the cases seen in the past. This change may reflect a greater tendency by the line community to remove students from training, or may reflect the improved selection of flight training candidates.

The cases seen by the board are now increasingly complex, reflecting improved diagnostic techniques, and changes in therapeutic modalities. By the time a medical problem of a naval aviator reaches a Special Board of Flight Surgeons, the board is intimately aware of the aviator, his aircraft and his disease state. A truly unique and individualized approach is taken, often with specifically delineated waiver requirements. The board is always cognizant that its recommendations may have far-reaching impacts. Standards in general are applied much more strictly to the aviation applicant than they are to the already designated aviator. The board realizes that some squadron members have truly unique capabilities and experience. In the final analysis the role of the board is to present the best possible aeromedical recommendation.

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FIT TO FLY. ANALYSIS OF THE AEROMEDICAL DISPOSITION IN AIRCREWMEMBERS OF THE SPANISH ARMED FORCES.

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INTRODUCTION

Medical fitness is an essential part of air safety. Aircrews undergo their regular medical review to ensure their physical and mental status will enable them to carry out their on-board functions in both normal and exceptional circumstances.
Medical screening during the selection process followed by continued medical vigilance over the health of aircrews has been the major contributor to air safety by reducing the risk of potential incapacitation during flying duty.
Because preexisting disease has been described as a contributor to aircraft mishaps (1), military aviators undergo detailed initial flying physical examinations designed to find those with physical defects or disabilities that could potentially compromise flying safety. Another major objective of the physical examination is to periodically reevaluate conditions already known to the pilot and flight surgeon which may or may not have required the granting of a waiver previously, as there are many medical problems or conditions which are not static but may become improved or worsened over the time interval since the last periodic check up (2).
Objective evaluation of experience in the aeromedical disposition and approach to various medical conditions of pilots will enable the application of more effective medical treatment, rehabilitation and consequently an improved waiver policy (3,4).
Leusden et al (5) in review of 2.697 pilots fo a 0.77 % of aircrew to have an operational flying restriction in any given year. They discussed the most common diagnoses and how refinements introduced over the past 5 years should help further reduce the incidence of these problems in experienced aircrew.
The decision whether to let a pilot fly again is always a difficult one, especially since the airman involved is usually very keen to return to duty and will do his utmost to convince those who make these decisions that he is capable of flying. Flight surgeons have the responsibility to confirm this capability prior to putting a pilot back in the cockpit. Equally important is the requirement that a sufficiently able pilot who has either recovered or been fully rehabilitated not be

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held from returning to flying duty. As aviation safety is paramount in aeromedical disposition, only a complete evaluation and detailed follow-up can be used in determining the aviator's ability or disability (6). The literature regarding the return of injured military aviators to active duty is scarce (7), although the ocurrence of preexisting disease in aircrew and conditions for which medical waivers cannot be granted, thus resulting in permanent disqualification from flying duties, has been reviewed (2,8,9,10).

The purpose of this study was:

1. To review the aeromedical disposition of Spanish military personnel through the first half of 1993 and identify the major reasons for permanent or temporary disqualification.

2. To determine the incidence of various medical causes for permanent or restricted status.

3. To determine the incidence and reasons for restrictions or temporary disqualification among aviators who, after appropiate follow-up were returned to flying duties.

MATERIAL AND METHODS

We reviewed the records of all the Spanish Armed Forces (SAF) aircrews who underwent their physical exam in the SAF Institute of Aviation Medicine (CIMA) during a six month period. The primary diagnosis initiating the flying dispositions and the recommended waivers were extracted.

Diagnoses were grouped by major disease categories:

1. Ophtalmology.

- Refractive errors
- Color vision disorders
- Tropia (strabismus)

2. ENT

- Hearing loss
- Sinusitis
- Tumor

3. Neuropsychiatric disorders.

- Personality disorder
- Depressive behaviour
- Migraine
- Seizure disorder

4. Cardiovascular diseases.

- Coronary artery disease
- Hypertension
- Arrythmia
- Mitral valve prolapse

5. Laboratory findings.

- Hypercholesterolemia
- Hyperglycemia
- Liver enzyme elevation
- Metabolic disorders
- Drugs

6. Miscellaneous.

- Medication/Drugs
- Degenerative spinal disease
- Limb fracture/Complications
- Positive HIV
- Asthma
- Alcohol abuse
- Ulcerative colitis
- Head injury
- Shoulder instability
- Pneumothorax
- Viral hepatitis
- Headache
- Tumor
- Others

Regulation regarding category system allows the following

flying restrictions.

a. Restriction:
Limitation to a certain flying duty or for a certain period of time.

b. Temporary disqualification:
Potential return to flying duties (either to restricted or unrestricted status).

We followed those aircrewmembers who were not permanently disqualified for a period of six months.
Statistical analysis of data was made utilizing data base provided by CIMA computarized system.

RESULTS

Of the 1769 physical exams 201 (first exam) or 139 (follow-up) of the total were found to have resulted in some type of aeromedical disposition.

Table I and II present the complete list of disqualifying medical conditions found and provides the basic data for discussion.
In order to facilitate future comparison of our data with that reported by other authors representing other NATO countries as well as with public health statistics regarding the wider populations of Spain, European Union etc., we have calculated both the relative percentages of affected personnel with regards to the total number of examinees and also as it related to the subpopulation of those airmen who required disposition of some type. Both percentages are listed on Table II.

The major reasons for permanent disqualification are visual problems related to colour vision or lack of adequate visual acuity, accounting for 0.45% of total examinees. We found only one case of refractive problems who was initially temporarily disqualified but finally permanently grounded. Permanent disqualification due to visual problems in the follow-up period of 6 months accounted for 0.52% of total examinees. There was no change in the number of airmen who were permitted to fly with some restrictions due to visual difficulties accounting for 3 out of the total examined (0.16%).

Auditory disease produced some changes in status as compared to initial disposition. Three cases (0.16%) were permanently disqualified due to hearing loss after the first exam. Another 2 examinees were placed on restricted duty status and remained so after 6 months. 27 airmen were temporarily disqualified. After the 6 month follow-up period 2 of the 27 were permanently grounded, bringing the total number of permanent disqualifications to 5 (0.28%). 6 others were deemed fit to fly and returned to full unrestricted duty while the remaining 19 flyers in this group continue to be maintained on temporarily disqualified status.

Neuropsychiatric diagnoses problems also resulted in an increased number of flyers permanently grounded compared to the initial action. Two (0.11%) of the examinees were grounded after initial examination. Two more (bringing the total to 0.22% of all examined) were also

eventually permanently disqualified after follow-up evaluation. These two additional cases were due to depressive behaviour and depressive neurosis. The same number of examinees representing another 0.22% of all aircrew who were evaluated, were deemed qualified to fly with restrictions. This remained unchanged after follow-up. The 17 who initially received temporary disqualifications, (0.96% of total) where reduced to 11 (0.62%) upon later follow up.
Four were returned to unrestricted flying duty while two represented those aircrew members mentioned above who were eventually permanently grounded.

There were no changes in disposition of flyers with cardiovascular disorders during the time interval between the initial and follow up examinations. Actions due to these problems led to 2 (0.11%) being permanently grounded, 7 (0.39%) made fit to fly with restrictions and 2 (0.11%) temporarily disqualified.

Laboratory findings requiring aeromedical disposition were related to hypercholesterolemia and elevated fasting plasma glucose in the range of 110-140 miligrams/dl. with normal glycohemoglobin (nondiabetic). The 65 flyers (3.67% of all examinees) who were granted qualified flying status with restrictions after initial evaluation were reduced to 41 individuals (2.31%) after follow-up. The 16 (0.90%) who were initially disqualified showed the greatest relative relative improvement in status with only 1 flyer (0.05%) remaining on dysqualified status. The other 15 were returned to full duty. This means that a total of 39 airmen (2.20%) graduated to unrestricted status on the basis of improved lab results, no doubt secondary to appropiate dietary and life style changes made by these aircrew members in the interim.

Miscellaneous reasons for aeromedical disposition ncluded a variety of problems such as medication not compatible with flying duties, degenerative spinal disease, limb fracture, presence of HIV antibody, asthma, alcohol abuse, ulcerative colitis, head injury, shoulder instability, pneumothorax, viral hepatitis and headache.
17 (0.96%) of examinees were placed on restricted status due to one of these various problems at the time of initial exam. 14 (0.79%) were mantained on restricted status after 6 months of follow-up evaluation.
These miscellaneous problems also resulted in 20 (1.13%) being temporarily disqualified initially. This was reduced to 11 (0.62%) during the ensuing 6 months with the others returned to unrestricted flying duty.

Analysis of our data as it relates to the total population evaluated shows that after the initial screening and selection process 16 (0.90% of all examined flyers) were permanently grounded. Another 87 (4.91%) experienced a period of temporary disqualification based on the initial exam. Finally, 98 (5.53%) aircrewmembers received a waiver restricting their duties, after their

initial evaluation.
A follow-up of all the aviators for a period of 6 months showed that 5 more cases (0.22%) were added to the 0.90% of those permanently disqualified. All five of these flyers had been initially placed on temporary disqualified status. On a positive note, however, 61 airmen (3.44% of all examinees) who had initially been placed on restricted duty status or had been temporarily disqualified were found "fit to fly" and returned to full unrestricted duty. This left 48 (2.71%) aircrew remaining temporarily disqualified while 71 others (4.01%) were allowed to participate in restricted flying duties.

DISCUSSION

A primary goal when addressing an aeromedical problem is to maximize operational safety by taking into account the individual circumstances of each aviator.
Medical evaluation of aircrew is designed to ensure mission completion by providing for the maintenance of the pilot's health and recognizing any condition that might present a hazard to flight safety.
The military aviator, having completed a long and expensive flight training program, represents a significant investment for any nation's military. This may result in the flight surgeon being pressured not to ground a highly qualified aviator when a problem is detected. These difficulties are minimized by strict adherence to an aeromedical disposition system enphasizing the use of methods that attempt to prevent problems before they occur. This and subsequent close follow-up of any problem that is identified should provide the tools that most likely be successful in allowing a military aviator to fly again whenever possible (5,6).
This methodologic identification of specific problems or potential disease and subsequent response to appropiate management and folowup provided the majority of data in our review.

With regards to aeromedical disposition due to ophtalmologic diagnoses no improvement in the number of flyers affected was noted during the 6 month period between the initial evaluation and follow-up. This can be atributed to the irreversible nature of almost all eye disorders other than trauma.

As mentioned earlier, 6 aircrewmembers of 32 who received some type of initial restriction or disqualification due to ENT problems were later found "fit to fly". These aviators who eventually recovered and returned to flying duties represented mild or reversible hearing loss or self limited inflammatory diseases. Whitton, in his review of USAF flyers, described a large number of patients with allergic rhinitis (9). We found no cases, probably due to selection procedures (disqualified in previous screening exam).

Neuropsychiatric disorders affected 23 aviators (1.30% of all airmen who were evaluated). A follow-up of these personnel showed that

only 4 pilots (0.22%) recovered completely, all of whom exhibited transient depressive behavior. This left us with a final rate of 1.07% of all aircrew members evaluated, having their flying duty affected in someway by neuropsychiatric illness.
Cardiovascular disease accounted for 11 pilots affected (0.62% of all examined), figures smaller than that reported in the literature (5,9). However the studies cited looked at the subpopulation of aircrew who had been permanently grounded while our data includes the additional subgroups of those either temporarily disqualified or on restricted flying status. As cardiovascular disease is generally an irreversible, progresively worsening process, it almost always results in permanent disqualification and therefore would represent higher percentage in the permanently grounded group than in the broader group of all airman affected by medical action. Still, a separate analysis of cardiovascular disease found that, in the 6 month period studied, it accounted for only 12.5% of all Spanish flyers who were permanently grounded. This compared to 42% and 30% described in Canadian and US studies respectively (5,9). This difference most likely reflects the generally higher prevalence of CV disease in North American populations than seen in Spain, as well a methodologic difference in the studies themselves (primarily the time span looked out).

Miscellaneous aeromedical problems showed, on the average figures similar to those described in previous studies in other Air Forces (3). However a positive finding in our study was the illustration of a meaningful decrease in aircrew members disqualified over the 6 month period of follow-up as 12 aviators (0.68%) from this group recovered and were returned to full unrestricted flying duties. Those were individuals that one would expect to recover based on the often self limited nature of the underlying disease processes that made up this "catch all" category, including orthopedic problems, pneumothorax, substance abuse, liver disease and headache.

Classic disease risk factors which are most applicable to the military aviator include lipid profile, smoking and regular exercise. The primary prevention of coronary heart disease is a widely discussed topic in the medical literature, especially in the area of appropiate lipid profile management (4). Thus, its should not be surprising that laboratory abnormalities were shown to be the major reason for temporary disqualification or restriction affecting 81 examinees (4.57% of total). This group contained the highest number of affected airmen who eventually returned to flying duties.
80% of the abnormal lab findings were related to metabolic disorders, the majority of these abnormal lipid profiles. Actual policy in our Institute is to carefully interview each aviator who presents coronary heart disease risk factors or any other metabolic abnormality included in the regular biochemestry lab

studies currently accomplished during the periodical physical exam.
All the categories of medical problems resulting in a change of flying status, the results of interventional efforts in those affected by metabolic derrangements were most promising, as almost half of those flyers restricted or grounded were eventually returned to duty.
The current aeromedical literature has emphasized the undertaking of preventive measures regarding risk factors that could lead to disease that might jeopardize future flying activities (1,4, 5,7,8,10). Early identification and active intervention in the disease process also play major roles in decreasing losses due to alcohol abuse, obesity, and other metabolic disorders. These problems are very easily followed-up and controlled through proper consulting while maintaining close vigilance.

CONCLUSIONS

Appropriate aeromedical guidance utilizing restrictions or temporary disqualifications should be one of the main goals of the flight surgeon in order to best employ the human resources of the NATO community.

A careful review and analysis of the findings in periodic physical examinations performed for the SAF during a 6 month period and the eventual actions and followup taken based on those findings reveals a certain degree of success in returning temporarily disqualified or restricted flyers to duty. The data demonstrated that the greatest number of successes were in those cases with either self limited processes (such as orthopedic problems and simple inflammatory diseases) or with disorders directly related to diet or life style (substance abuse including alcohol, hyperlipidemia, transient depression, hypertension). This clearly illustrates the importance of active intervention and close follow-up by aeromedical personnel in these affected aviators and urges the continued development of specific programs targeted at the disease states that are both the most commonly found and most amenable to the treatment rendered by the flight surgeon.
Only an active program such as this can assure the continued maintenance of flight safety and optimal use of our human resources.

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FIRST EXAM
Disposition

	Permanently Grounded	Restricted	Temporarily Dysqualified	Fit
OPHTALMOLOGY				
Refractive errors	2		5	
Color Vision	5	3		
Tropia (Strabismus)	1			
TOTAL	8	3	5	
ENT				
Hearing loss	3	2	21	
Sinusitits			4	
Tumor			2	
TOTAL	3	2	27	
NEUROPSYCHIATRIC				
Psychiatric disorders			2	
Personality disorders		2	8	
Depressive Beharior		2	7	
Seizeures	2			
TOTAL	2	4	17	
CARDIOLOGY				
CAD			2	
HTA		3		
Arrythmia	1	4		
Mitral Valve Prolapse	1			
TOTAL	2	7	2	

Table I-1. Disqualifying aeromedical conditions

FIRST EXAM
Disposition

	Permanently Grounded	Restricted	Temporarily Dysqualified	Fit
LAB				
Hypercholesteronemia		53	10	
Hyperglycemia			3	
Liver enzyme elevation		12		
Metabolic disorders			1	
Drugs			2	
TOTAL		65	16	
MISCELLANEOUS				
Drugs		1	4	
Degenerativa Spinal Disease		1	3	
Limb FX/Consequences		1	3	
Positive HIV			1	
Asthma	1	1	1	
Alcohol abuse		1	1	
Ulcerative Colitis			1	
Head injury		1		
Shoulder inestability			1	
Pneumothorax			1	
Viral hepatitis		2	1	
Headache		1	1	
Tumor		1	1	
Others		7	1	
TOTAL		17	20	

Table I-2. Disqualifying aeromedical conditions

FOLL OW-UP
Disposition

	Permanently Grounded	Restricted	Temporarity Dysqualified	Fit
OPHTALMOLOGY				
Refractive errors	3		4	
Color vision	5	3		
Tropia (Strabismus)	1			
TOTAL	9	3	4	
ENT				
Hearing loss	5	2	19	6
Sinusitis				
Tumor				
TOTAL	5	2	19	
NEUROPSYCHIATRIC				
Psychiatric disorders	1			
Personality disorder		2	[illegible]	4
Depressive behavior	1	2	6	
Seizeures	2			
TOTAL	4	4	11	
CARDIOLOGY				
CAD			2	
HTA		3		
Arrythmia	1	4		
Mitral Valve Prolapse	1			
TOTAL	2	7	2	

Table I-3. Disqualifying aeromedical conditions

FOLLOW-UP
Disposition

	Permanently Grounded	Restricted	Temporarily Disqualified	Fit
LAB				
Hypercholesteronemia		34	1	
Hyperglycemia		3		
Liver enzyme elevation		4		39
Metabolic disorders				
Drugs				
TOTAL		41	1	
MISCELLANEOUS				
Drugs		0	3	
Degenerative Spinal Disease		1	2	
Limb FX/Consequences		1	0	
Positive HIV			1	
Asthma	1	1	1	
Alcohol abuse		1	1	
Ulcerative colitis			1	
Head injury		1		12
Shoulder Inestability			0	
Pneumothorax			0	
Viral hepatitis		2	0	
Headache		0	0	
Tumor		1	1	
Others		6	1	
TOTAL	1	14	11	

Table I-4. Disqualifying aeromedical conditions

FIRST EXAM

	Permanently Grounded	Restricted	Temporarity Dysqualified	Fit
OPHTALMOLOGY (OUT OF 1769)	8 = 0.45%	3 = 0.16%	5 = 0.28% -1	
(OUT OF 201)	4%	1.49%	2.48%	
ENT (OUT OF 1769)	3 = 0.16%	2 = 0.11%	27 = 1.58% 8	
(OUT OF 201)	1.49%	0.99%	1.34%	
NEUROPSYCHIATRIC (OUT OF 1769)	2 = 0.11%	4 = 0.22%	17 = 0.96% -6	
(OUT OF 201)	0.99%	1.99%	8.45%	
CARDILOLOGY (OUT OF 1769)	2 = 0.11%	7 = 0.39%	2 = 0.11%	
(OUT OF 201)	0.99%	3.48%	0.99%	
LAB (OUT OF 1769)		65 = 3.67%	16 = 0.90%	
(OUT OF 201)		32.33%	7.9%	
MISCELANEOUS (OUT OF 1769)	1 = 0.05%	17 = 0.96% -3	20 = 1.13% -9	
(OUT OF 201)	0.49%	8.45%	9.95%	
TOTAL POPULATION	16 = 0.90%	98 = 5.53%	87 = 4.91%	

Table II-1. Percentage of aeromedical conditions

FOLLOW-UP

	Permanently Grounded	Restricted	Temporarily Dysqualified	FH
OPHTALMOLOGY (OUT OF 1769)	9=0.50% +1	3=0.16%	4=0.22%	
(OUT OF 139)	6.47%	2.15%	2.87%	
ENT (OUT OF 1769)	5=0.28%	2=0.11%	19-1.07%	6
(OUT OF 139)	3.59%	1.43%	13.66%	
NEUROPSYCHIATIC (OUT OF 1769)	4=0.22%	4-0.22%	11-0.62%	4
(OUT OF 139)	2.87%	2.87%	7.91%	
CARDIOLOGY (OUT OF 1769)	2-0.11%	7=0.39%	2=0.11%	
(OUT OF 139)	1.43%	5.03%	1.43%	
LAB (OUT OF 1769)		41-2.31%	1=0.05%	39
		29.49%	0.71%	
MISCELLANEOUS (OUT OF 1769)		14-0.79%	11-0.62%	12
(OUT OF 139)		10.07%	7.91%	
TOTAL POPULATION				
	21=1.13%	71=4.01%	48=2.71%	61=3.44%

Table II-2. Percentage of aeromedical conditions

AMDRS: A RESOURCE FOR INTELLIGENT AEROMEDICAL DECISION-MAKING

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SUMMARY

INTRODUCTION. The Aviation Medical Data Retrieval System (AMDRS) is a dynamic, expanding database that currently contain information on 150,000 individuals, and approximately 75,000 separate complete examinations. The Naval Aerospace and Operational Medical Institute (NAMI) developed AMDRS in March 1989. The Aviation Epidemiological Data Register (AEDR), developed by the US Army Aeromedical Research Laboratory, is the temporary repository of information from which the AMDRS develops. After the medical record is completed by reviewers, information is transferred for permanent storage in the Aviation Medical Data Base (AMDB). The purpose of this paper will be to provide detail about the information available in the database, examples of previous studies completed, and propose specific areas for future study. METHODS. Since 1987, all current Naval aviation personnel have had their status entered into the AMDB. Since 1990, all Naval aviation physical examinations submitted to NAMI for endorsement of physical qualifications or waivers have had the data from the SF-88 (Report of Medical Examination) entered into the AMDB. As the examination proceeds through the review/endorsement process, additional data is added to the AMDB; including a list of all disqualifying conditions, along with their corresponding ICD-9-CM codes, and aeromedical disposition. Subsequent examinations are also entered into the AMDB, often on a yearly basis if the individual is on a waiver. RESULTS. To date, approximately 150,000 different individuals have had their status entered in the AMDRS, and approximately 75,000 separate examinations have been entered. CONCLUSIONS. The AMDRS provides an extensive data base from which retrospective studies can be performed to validate the current aviation physical standards, the clinical rationale for aeromedical disposition, and the setting of new standards, as appropriate. The potential number of epidemiological studies offered by the database is limitless and mandates further study.

LIST OF SYMBOLS

AAC	Aeromedical Advisory Council
AEDR	Aviation Epidemiological Data Register
AMDB	Aviation Medical Data Base
AMDRS	Aviation Medical Data Retrieval System
BUMED	Bureau of Medicine and Surgery
BUPERS	Bureau of Naval Personnel
CD	Considered Disqualifying
CMC	Commandant of the Marine Corps
CNO	Chief of Naval Operations
CNRC	Commander, Naval Recruiting Command
ICD-9-CM	International Classification of Diseases
NAMI	Naval Aerospace and Operational Medical Institute
NCD	Not Considered Disqualifying
NPQ	Not Physically Qualified
PC	Personal computer
PQ	Physically Qualified
RPOW	Repatriated Prisoner of War
SF-88	Report of Medical Examination
SF-93	Report of Medical History
SSN	Social Security Number
USCG	United States Coast Guard
USMC	United States Marine Corps
USN	United States Navy

BACKGROUND

The Naval Aerospace and Operational Medical Institute (NAMI Code 42), in its capacity as Bureau of Medicine and Surgery (BUMED-236), is the disposition center for all aeromedical issues for the United States Navy and the United States Marine Corps. The Institute is responsible for reviewing all aviation physical examinations for

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Naval aviation, including all Navy and Marine Corps officer and enlisted candidates, all Coast Guard student aviators, as well as all designated aviation personnel for the Navy and Marine Corps. Additionally, the Institute advises the U.S. Navy Surgeon General on all aeromedical policy and aviation physical standards for over twenty-five types of various aviation duty examinations.

A component of the Institute is the Aeromedical Advisory Council, a panel of aerospace medicine specialists with extensive operational experience and clinical specialists including Internal Medicine, Ophthalmology, Otorhinolaryngology, and Psychiatry. This panel utilizes its collective experience and specialty background to advise the Commanding Officer of policy recommendations to be made to the Surgeon General. Aeromedical decision-making by the group is aided by the data included in the Aviation Medical Data Retrieval System (AMDRS), which will be described in this paper.

DESCRIPTION OF THE AMDRS

The Aviation Epidemiological Data Register (AEDR), developed by the US Army Aeromedical Research Laboratory, is the temporary repository for information from which the AMDRS (Aviation Medical Data Retrieval System) is developed. NAMI (Naval Aerospace and Operational Medical Institute) developed the AMDRS (Aviation Medical Data Retrieval System) in March 1988. The AMDRS (Aviation Medical Data Retrieval System) is an integrated aviation medical database system specifically designed to improve support to Navy and Marine Corps Aviation personnel. Micro-88, personal computer (PC) based software, was developed as a tool to be utilized by field activities and is the entry point for the primary data entered into the AEDR (Aviation Epidemiological Data Register). The AEDR (Aviation Epidemiological Data Register) and AMDRS (Aviation Medical Data Retrieval System) are maintained on a VAXcluster at the Institute. An assortment of relational databases provide for easier, more rapid extraction of data for a multitude of purposes. The program language is Fortran.

Micro-88 enables field activities to enter all of the information contained on the Standard Form 88 (SF-88), Report of Medical Examination. In addition, limited information from the Report of Medical History, Standard Form 93 (SF-93), or the Officer Physical Examination Questionnaire, NAVMED 6120/2, is included. The entry of this data is currently limited because it is narrative in nature. Future efforts, to be described, will provide for more complete entry of this information. The majority of the information on the SF-88 (Report of Medical Examination) is numerical, lending itself to ready storage, retrieval, and analysis. All conditions which are Considered Disqualifying (CD), i.e. outside of aviation standards, are coded using the International Classification of Diseases (ICD-9-CM).

To provide quality assurance of the information entered into the database, medical treatment facilities are able to review their examinations for completeness for the type of examination entered through the software provided by Micro-88. These facilities are able to access the VAXcluster via modem. Through the VAX, the examinations can be reviewed for conformance to standards depending upon the type of examination. Presently, forty-four facilities, which account for approximately 80% of all aviation physical examinations submitted for review, have Micro-88 capability. For facilities without Micro-88 capability or the ability to electronically transmit information, the hard-copy forms of the examinations are mailed to NAMI (Naval Aerospace and Operational Medical Institute). At NAMI, the data from these examinations is entered into the database by contract data operators, who utilize the AEDR (Aviation Epidemiological Data Register) "double data" entry system, followed by a checker to resolve discrepancies, which minimizes errors. This redundancy allows for accurate entry of data into the database.

Also included on the VAX super minicomputer, and available to facilities with Micro-88 and modem capability, is a summary of the waiver history for various diagnoses by ICD-9-CM code. This utility allows a facility to immediately assess the probability of a favorable waiver recommendation by diagnosis code and by Class and Service Group of personnel. A utility also exists which enables facilities to determine current aeromedical disposition

Table I The Aviation Medical Data Base (AMDB)
Size and Record Distribution

Number of records in the personnel file	102,699
Number of records processed since 1987	170,960
Number of unique SSN's processed since 1987	74,932
Number of SF-88's entered since 1990	96,183
Number of SF-88's with unique SSN	53,014
Number of records processed for waiver	40,689
Number of unique SSN's processed for waiver	20,922

policy and the requirements for submission of a waiver request for over 180 diagnoses, which account for nearly 80% of all waiver requests.

NAMI (Naval Aerospace and Operational Medical Institute) also maintains a microfiche file on which are recorded all hard-copy information that is submitted on each aviator. This provides an invaluable back-up of information which can be extracted when the information would not be included in the database. The additional information is critical for some research projects. Future plans call for all information to be stored as an image on the VAXcluster, allowing it to be catalogued, and subsequently retrieved from a much-expanded database. Funding for this project is being aggressively pursued.

EXTENT OF THE PRESENT DATABASE

Microfiche records have been maintained since 1970. There are 180,000-200,000 individuals' records on microfilm. Since 1987, all current Naval aviation personnel have had their status entered into the Aviation Medical Data Base (AMDB). This means a record of whether the individual is physically qualified (PQ) or not physically qualified (NPQ), as well as whether a waiver was or was not recommended, and their duty status, i.e. Class, Service Group, or specific type of aviation duty. Since 1990, all Naval aviation physical examinations submitted to NAMI (Naval Aerospace and Operational Medical Institute) for endorsement of physical qualifications or waivers have had the data from the SF-88 (Report of Medical Examination) entered into the AMDB (Aviation Medical Data Base). Since the requirement exists for all enlisted aviation personnel to have examinations submitted at candidacy, and all officer personnel to have examinations submitted at candidacy and at least every three years thereafter, the present database has existed long enough to include all personnel currently on active flying status. This number is approximately 100,000. To date, 170,960 different examinations have been entered by status in the AMDB, with 74,932 unique SSN's (individuals) entered. Since 1990, 96,183 SF-88's (Report of Medical Examination) have been entered into the AEDR (Aviation Epidemiological Data Register), representing 53,014 unique SSN's. The personnel file contains 102,699 distinct records by SSN. (Table I).

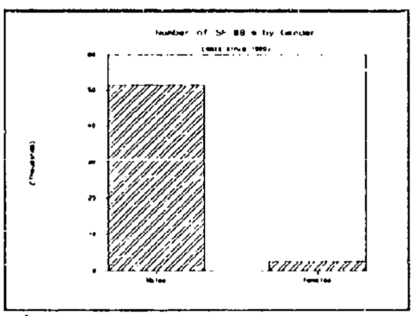

Figure 1 Records by Gender

As of January 1994, the database included records on 51,496 males and 2,538 females (Figure 1). The age distribution includes age 18 to age

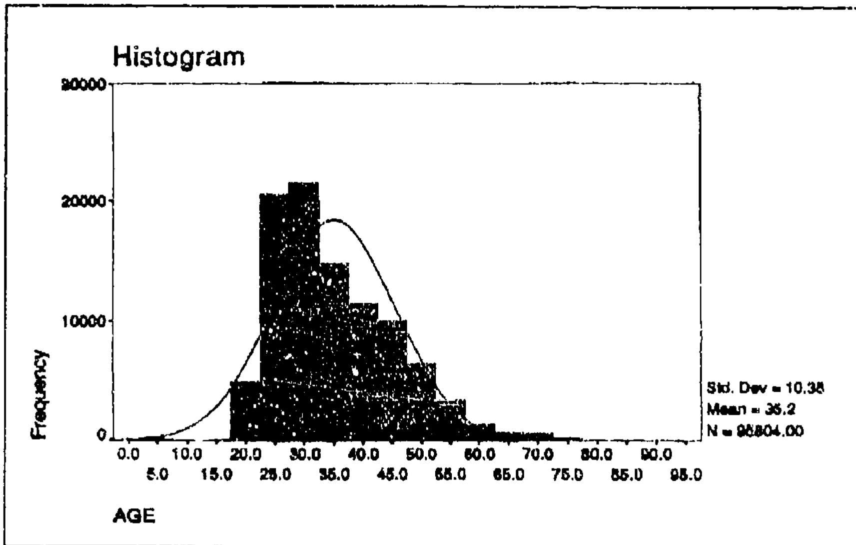

Figure 2 Age Distribution

78. The mean age of personnel in the database is 35 (Figure 2). There are 38,949 Class I personnel (those in actual control of aircraft) and 106,396 Class II personnel (all others serving in aviation duty). Of the Class I personnel, there are records on 37,632 Service Group 1, 1,038 Service Group 2, and 279 Service Group 3. A total of 40,689 records have been processed for waivers to the physical standards, representing 20,922 separate individuals. Although the waiver utility on the VAX does not provide detail about all of the Class II personnel, because at least three blocks on the SF-88 (Report of Medical Examination) indicate the type of examination or duty status, data can be extracted by very specific types of duty.

As the examination proceeds through the review/endorsement process, additional data is added to the AMDB (Aviation Medical Data Base); including a list of all disqualifying conditions, along with their corresponding ICD-9-CM codes, and aeromedical disposition. Subsequent examinations are also entered into the AMDB, often on a yearly basis if the individual is on a waiver.

PREVIOUS STUDIES CONDUCTED FROM THE DATABASE

In 1990, an extensive evaluation was conducted producing the Aviatrix results. This study utilized all the information maintained in the database as it was an analysis of all SF-88 (Report of Medical Examination) items and ICD-9-CM diagnoses for all of the women in Naval aviation. The results of the study have been used on numerous occasions, not the least of which was during the recent debates on "Women in Combat."

The anthropometric standards were developed based on the Naval Air Systems Command analysis of cockpits in the inventory at the time the standards were established. This clearly resulted in the necessity of the pilot being selected to fit the cockpit. More recently, the anthropometric data maintained in the database is being utilized in designing and re-designing cockpits. This information does not reside in any other readily accessible form, underlining the importance of the database in the decision-making process, not only for aeromedical decisions, but also fo design efforts in the man-machine interface.

Whenever the Aeromedical Advisory Council examines an issue for potential policy change, the database

becomes an invaluable source of information, revealing not only the extent of the problem, but also an indication of previous aeromedical disposition. This foundation provides the basis for much more scientific recommendations to the Surgeon General as aeromedical policy is formulated.

During 1991, the idea was born to change the frequency of submissions of aviation physical examinations for those who had a waiver of standards to continue flying. By determining the frequency of waivered diagnoses, a more intelligent recommendation with greater impact was developed. An analysis of the data led to a recommendation to reduce the frequency of submission for BUMED endorsement of certain conditions for waiver continuance which had been determined to not progress adversely during the aviator's career. This has led to an easing of the burden on local flight surgeons, medical treatment facilities, and BUMED-236, reducing man-hours and costs, without having an adverse effect on aviation safety.

The users of this extensive database extend far beyond the aeromedical community. Included among the activities using information from the database in their decision-making processes have been the Chief of Naval Operations, the Chief of the Bureau of Naval Personnel, and the Commandant of the Marine Corps. The database is widely recognized as a resource that leads to intelligent decision-making.

Numerous examples of the application of the database are exemplified by a review of historical utilization of the database. The Commandant of the Marine Corps has used an analysis of the number of candidates found Not Physically Qualified and without a recommendation for waiver to predict the number of candidates who must be selected for aviation slots in order to meet pilot training requirements. When the United States Marine Corps was considering the use of contact lenses for certain designated pilots, the database was an invaluable resource for determining the potential impact of such a decision by assessing the number of Marine aviators, flight officers, and aircrewmen with visual acuity less than 20/20 uncorrected. The United States Marine Corps re-evaluated their weight limit standards following a review of the number of their designated aviators who exceeded their previous maximum weight standard, but weighed within the design limits of the ejection seats in current aircraft.

The Naval Air Warfare Center Aircraft Division has utilized the anthropometric data to aide in the development of an advanced anti-G garment. The Chief of Naval Operations utilized anthropometric data for women Naval aviators to assess the validity of cockpit fit checks by the Naval Aviation Schools Command in assigning individuals to various aircraft pipelines. Most recently, the Presidential Commission on Women in the Armed Forces analyzed the number of pilots who have become pregnant while serving in a flying assignment.

Visual acuity standards for candidates were re-addressed following an inquiry by the Officer Community Manager of the Bureau of Naval Personnel. Subsequently the visual acuity standard for applicants to pilot training was changed.

The Naval Aerospace Medical Research Laboratory has made numerous inquiries of the database, including identification of hypertensive aviators. Other diagnoses that have been investigated by the Naval Aerospace and Operational Medical Institute include coronary artery disease, ventricular septal defects, those leading to determination of Not Aeronautically Adaptable, and defective depth perception and its relation to defective uncorrected visual acuity.

The database has also been utilized for quality assurance purposes, i.e., what are the numbers of individuals found Physically Qualified by medical treatment facilities at other locations in the country, but found Not Physically Qualified once reporting for initial flight training at Naval Air Station Pensacola.

FUTURE UTILIZATION OF THE AMDB

In 1989, the visual acuity standard for entrance to Navy pilot training was changed. The capability now exits with the AMDB (Aviation Medical Data Base) to assess the rate with which the visual acuity of these individuals has changed and whether the Navy is losing the services of its trained pilots earlier because these individuals' visual acuities deteriorate outside the standards for Service Group I or Service Group II

before their career in flying is complete. The distinction among the various service groups determines whether a pilot is able to fly on and off of the ship, or must fly with another pilot qualified in airframe type (i.e. dual-controlled aircraft). The outcome of such a review could have a large monetary impact on Naval aviation. The information exits within the database to determine such outcomes.

As the value of this database for epidemiological purposes becomes more widely recognized, other warfare specialties and agencies have gained interest in its use. Should other warfare specialties elect to utilize a similar system, the power of the database in statistical analysis would multiply. Likewise, bringing the United States Air Force and United States Army aviator physical examination data and waiver history into the database would further increase its value for aeromedical decision-making.

Other databases are also maintained on the VAXcluster. Included among these are the results of the Aviation Selection Test Battery, which is administered to all potential pilot and Naval Flight Officer candidates for Naval aviation and utilized in the selection process. Combining the information in this database provides an additional tool for pilot and Naval Flight Officer selection.

Finally, the data from the Repatriated Prisoner of War (RPOW) study and the 1000 Aviator Study are currently being added to the VAXcluster. Information from these studies increases the longitudinal value of the database, and could be utilized to further validate the appropriateness of aeromedical standards and waiver recommendations.

The utility of the database in aeromedical decision-making can expand further. For example, currently any aviation personnel with a history of seasonal allergic rhinitis (SAR) after age twelve require a waiver to be on flight status. By evaluating the outcome of those on waivers for SAR, it may be possible to alter the requirements for waiver or waiver continuance submission, particularly if an adverse outcome from these waivers is not identified. This same concept could be applied to any other frequently waivered condition. The end result of such an analysis could be a substantial savings in both time and money.

CONCLUSIONS

In summary, the Aviation Medical Data Retrieval System (AMDRS) has proved its utility in several aeromedical decision-making processes in the past. The power of the database grows daily, both in terms of numbers added to the database as well as overall scope of the database. Future analysis of the data can be utilized to review and revise aviation physical standards, as well as analyze the waiver recommendation process for its impact on aviation safety. As resources diminish for support of the military aviation structure, the ability to formulate intelligent aeromedical standards and policy is paramount and grows in value. It is paramount that we select for training the best individuals and those who can be maintained safely in a flight status. As efforts are increased in a joint climate, the ability to compare experience among the United States Navy, United States Air Force, and the United States Army, grows in value. Additionally, the ability to study the epidemiology of the aviation community is invaluable.

The AMDRS (Aviation Medical Data Retrieval System) provides an extensive data base from which retrospective studies can be performed to validate the current aviation physical standards, the clinical rationale for aeromedical disposition, and the setting of new standards, as appropriate. The potential number of epidemiological studies offered by the database is limitless and mandates further study.

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RELEVANCE OF LABORATORY TESTS IN AEROMEDICAL DECISIONS

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Laboratory tests in body fluids are an essential part of the aeromedical examination. It helps to find objective data in a poor anamnesis. Nearly all pilots tell us they feel healthy and fit for flying duty. The chemical finding sometimes give surprising results. Measurements are of a high technical standard, quality control guarantees reliability. So noone can ignore an abnormal laboratory measure. The range of test profiles in aeromedical examination in civil and military regulations is different.
Our laboratory program for pilots is now reformed and will be part of the regulations for the aeromedical examination.
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-Test is sufficient specific and sensitive.
-Test can be automated and economically performed.

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laboratory data, regarding urine analysis, BUN, creatinin, are often first sign of kidney desease.
Most important is proteinuria in the range of 100 mg/dl leading to asymptomatic glomerulonephritis or cystic degeneration including slight elevation of creatinin. This get normally apparent in the first examination in pilot applicants. In the periodic screening the hematuria was sometimes the only clinical sighn of an malignoma of kidney and bladder. On the other side urin findings are often not reproducible and must be repeated before final diagnosis.

Function of Liver.
Enzymes and Bilirubin must be determined in everyone. In our experiance elevated Bilirubin was never cause of medical decision. Normally Meulengracht anomaly without relevance must be assumed. In about 10 % of our pilots this is the case.
Enzymes are not really specific but they may lead to a chronic infectiuos hepatitis or alcoholabusus, which has to be confirmed by specific diagnostic procedure.
Inapparent chronic infectious hepatitis must be excluded especially in those, who will be sent in tropical areas, because the possibility of manifestation. Our screening program includes Anti HBc, HBSAG, AntiHCV. HAV is not known for persistent infection, but it is necessary for decision of immunisation to check Anti HAV. A hepatitis-screening program for each pilot may be an ecomomical problem, because their high expenses. It is demanded for all soldiers sent to tropical aereas.
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Presented at a Symposium on 'The Clinical Basis for Aeromedical Decision Making', April 1994.

RELEVANCE OF LABORATORY TESTS IN AEROMEDICAL DECISIONS

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Laboratory tests in body fluids are an essential part of the aeromedical examination. It helps to find objective data in a poor anamnesis. Nearly all pilots tell us they feel healthy and fit for flying duty. The chemical finding sometimes give surprising results. Measurements are of a high technical standard, quality control guarantees reliability. So noone can ignore an abnormal laboratory measure. The range of test profiles in aeromedical examination in civil and military regulations is different.
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special laboratory data evaluation. In 1983 Feuerlein and coauthors discriminated patients with alcoholabuse by high normal and elevated ALT,AST,GGT,MCV and low Creatinin and Urea (1). We tried this many years, but we feel it is not specific. Only elevated both Gamma GT and MCV are clear findings. Since 1994 we test the new parameter carbohydrate deficient transferrin (2). This is determined by RIA. We can distinguish Gamma GT elevation by alcohol intoxication and other disorders.

Lipid screening

Lipid monitoring is mainly part of preventive medical programs (3). There is less aeromedical significance. Even in the possibility of sudden heart failure it may be regarded. There is no doubt,LDL cholesterol is a risk factor in CHD. Heart and circulation problems are the most frequent medical causes of licence loss in internal medicine. Not cholesterollevel, but clinical manifestation, in blood pressure or ECG, made the decision.The employer has a high interest to keep the pilot as long as possible in a flying status. Elevated cholesterol can be treated and the risk reduced. Nearly all elder pilots exceed the range of 200 mg/dl cholesterol which is suggested by the German arteriosclerosis association for intervention. In exceeding level test must be completed by triglycerides, HDL-,and LDL cholesterol. The borderline for LDL-cholesterol of 160 mg/dl is also exceeded mostly, but people can be motivated to regard this in their lifestyle. For further determination of cardiac risk, we propose the LPa. The problems in LPa are the lack of an automated testsystem. It is also not known,how to manage elevated LPa.

Aeromedical decisions only by Hyperlipidemia is made exclusively in applicants initial examination.20 applicants were in 1993 rejected by internal medicine disorders.2 of them had excessive familiar hypercholesterinemia.

Metabolic syndrome.

Metabolic syndrome includes diabetes typ II, hyperuricemia, secondary hyperlipemia.It is also a risk of CHD.Diabetes mellitus has the highest aeromedical relevance.Therefore we created following procedure: In all initial examinations a glucose tolerance test.

In the yearly examination fasten Blood glucose and postprandial blood glucose.

In many years we find oGTT is not sufficient for screening in the yearly examination because its lack in specificity (4). But because its high sensitivity it is possible to exclude safely diabetes in young people. The postprandial blood glucose gives in our experiance not more additional information in carbohydrate tolerance, than fasten blood glucose alone.

Metabolic syndromes are sometimes very difficult aeromdedical decision. This may be illustrated in one typical history:

In 1989 a 40 years old helicopter pilot 100 kg, blood pressure 160/110 mmHg has following laboratory findings: Fasten blood glucose 147 mg/dl,no glucosuria, triglycerides 374 mg/dl,cholesterol 274 mg/dl,gamma GT 33 U/l.

The decision revealed: not qualified for flying status for 3 month. Findings get better while trying hard to loose some kg.

and he get back to flying status. In 93 again hyperlipemia in the range of 217 mg/dl LDL cholesterol, gamma GT 39, uric-acid 8,7 mg/dl, normal bloodglucose and blood pressure, but still excessive overweight. The decision was now DNIF and repeated examination within 3 month at our institute. In 94 his weight was still 97 kg, but all laboratory results were nearly normal. We are sure, he will get aeromedical problems again and again.

Anti HIV test.
HIV infections are of high aeromedical relevance mainly because the possibility of neurological and psychiatric complications. Even asymptomatic infections are a safety risk and must be excluded from flying duty. HIV tests in GAF are strongly optional and cannot be part of the periodical medical examination. Therefore the GAF-IAM started since 1988 an information program encouraging the pilots for HIV Testing. Now 10% with increasing tendency sign for a test. Up to this time we found in about 600 tests a year no positive results.

Most reasons of disqualifing for flying duty in internal medicine reasons are cardiovascular disorders. The next table is showing the disqualified, which get apparent only by laboratory results.

	all disqu.	kidney disorder	liver enzyme	metabolic disorder
annual exam.	63	1	1	2
initial exam.	20	2	1	2

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TSH DETERMINATION IN SUBJECTS WITH MEDIUM-LOW LEVELS OF SERUM THYROXINE

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SUMMARY

The prevalence of thyroid diseases is almost 5 to 7 %. Hypothyroidism, whether primary (thyroidal) or secondary (hypothyrotropic and, rarely, hypothalamic) occurs at all ages and is more common in women. Its frequency varies depending on the population studied. The prevalence of overt hypothyroidism is 0.5 to 2 %. Even though hypothyroidism is an uncommon cause of disease, it nevertheless decreases psychological and physiological efficency, modifing the aeromedical standards.

Hypothyroidism is an involved clinical, metabolic condition supported by inadequate thyroid function. Elevation of thyrotropin blood levels is a sensitive indicator of decreased thyroid gland function (primary hypothyroidism).

In this study we evaluated the prevalence of subclinical hypothyroidism, characterized by an elevation of TSH levels with low levels of serum thyoxine and medium-low levels of free tiroxine, in subjects examined at thr Forensic Medical Institute of IAF, during ordinary checkups.

We investigated on 35 people, military and civilian, aged from 25 to 70 years with low blood thyroxine (RIA) levels (65-115 nmol/ml versus normal values of 65-157 nmol/ml). Patients with non thyroidal illness, those on medications affecting thyroxine and those with thyroid disease were excluded from the study. Determinations of thyrotropin hormone (IRMA) were obtained on the 35 subjects. Elevation of thyrotropin was found in 12 persons. Six of these were started on thyroxine therapy with L-thyroxine (50 μg/die).

Thyrotropin hormone elevation is an early indicator of decreased thyroid function and subclinical hypothyroidism may be recognized by thyrotropin screening in subjects with medium low levels of serum thyroxine.
In aeromedical evaluation the screening is reccommended for selection and suitability to fly.

1 INTRODUCTION

The clinical syndrome of hypothyroidism was first described by Gull in 1874 (Ref 1), the term myxedema was coined by Ord four years later (Ref 2). Although myxedema was not a constant feature of hypothyroidism, the two terms are, even today, often erroneously used synonymously. It was also widely accepted in the past that hypothyroidism was an "all or none" phenomenon. With the advent of precise diagnostic techniques to measure thyroid function, however, it became clear that hypothyroidism is a graded phenomenon in which myxedema presents the fully developed and often far advanced syndrome.

Hypothyroidism can be defined as the clinical, biochemical and metabolic syndrome resulting from inadequate thyroid hormone production and sub-normal thyroid hormone concentration or, from faulty transduction of the thyroid hormone message (Ref 3). The inadequate production may be caused by disorders of the thyroid gland itself, by anterior pituitary insufficiency or, uncommonly, by hypothalamic abnormalities (Ref 4). Resistance to the action of thyroid hormones is a very rare cause of hypothyroidism (Ref 5)

Hypothyroidism may occur at all ages and has different characteristics and consequences at different stages of life. It is much more common in females (F/M = 4.7/1) and in the elderly (Ref 6). Clinical evidence of hypothyroidism varies widely However, the clinical and laboratory assessment of thyroid function permits the definition of two groups of hypothyroidism at least, distinguishing clinically

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Tab. 1-Subclinical hypothyroidism screening review

Reference	Year	Subjects	Cases of Hypothyroidism	
			Pz with unsuspected Overt Hyp.	Pz with Subclinical Hypothyroidism
Tunbridge	1977	2779	0	28 (TSH>6)
Hodkinson	1977	114	17	not given
Sawin	1979	374	32	27 (TSH>10)
Nystrom	1981	1283	0	12 (TSH>6)
Campbell	1981	427	9	not given
Falkenbeg	1983	1442	6	11 (TSH>7)
Brochmann	1988	200	12	24 (TSH>6)
Okamura	1989	2421	4	33 (TSH>4,1)
Present study	1993	1150	0	12 (TSH>3)

apparent disease from earlier grades of thyroid disfunction: overt" hypothyroidism and "subclinical"hypothyroidism (Ref 7). In the former, the patients present signs and symptoms that indicate an abnormal function of one or more systems. In the latter, patients have no signs or symptoms of hypothyroidism but present an elevated serum TSH concentration with normal or slightly low levels of thyroid hormone concentration (Ref 8,9). Subclinical hypothyroidism is found in about 7,5% of women and in about 3% of men (Ref 10). Prevalence rates of overt hypothyroidism vary from 0.5 to 2% in women (Ref 11) and may be as high as 4% in elderly women (Ref 12). Diagnosis, evaluation and management of subclinical hypothyroidism is very important because overt hypothyroidism develops in a certain number of these patients: in the Tumbridge study (Ref 13) 8 % of the patients with TSH levels over 6 mU/L developed overt hypothyroidism within 5 years (Tab 1).

Subclinical hypothyroidism has significant effects on some peripheral target organs at an early stage (Ref 10). It appears to be a risk factor for atherosclerosis and for coronary heart disease (Ref 14; 15), and may cause an evident impairment of some cognitive functions correlated to memory, as well as behavioural alterations (Ref 16). Neuropsychological and behavioural features are an important problem for the efficiency of certain categories of people.
In order to be useful in making aeromedical decisions for selections and suitability to fly, the aim of this study was to evaluate the utility of wider application of TSH assay as a primary screening test to detect subclinical hypothyroidism.
It is important to identify potential patients who show possible morbidity and who could develop overt hypothyroidism over time.

2 SUBJECTS AND METHODS

Subjects

From May to July 1992, 1150 subjects of flying personnel were screened for thyroid function at the Forensic Medical Institute of the Italian Air Force, during ordinary checkups. 35 patients (3.1%), among whom 23 women and 12 men, with low blood total T4 (TT4, RIA) levels (65-115 nmol/ml) and medium-low levels (7.9-16.5 pmol/ml) of FT4 (RIA), were examined by TSH (IRMA). The subjects ranged in age from 25 to 70 years with a mean age of 35,6 years. Those with non thyroidal illness or on medication affecting TT4 and those with thyroid disease were excluded from the study.
The following thyroid function tests were done: total T4 by RIA, free T4 estimates by RIA (FT4), sensitive thyrotropin

(TSH) IRMA and stimulatig tests with Thyrotropin releasing hormone (TRH test). All assays were carried out exactly as indicated in the manufactures instructions. All tests were done in duplicate and rechecked if the duplicates varied by more than 10%.
The patients population was correlated with a euthyroid group of 50 normal controls with no thyroid history (mean age 39.2 years). All patients and controls were in good general health.

Hormone assay

Evaluation of plasma TSH levels, (normal values less than 3 mU/L) was performed by an ultrasensitive immunoradiometric assay (Technogenetics, Milan, Italy) with a detection limit of 0,2 mU/l. TSH response was also evaluated by TRH stimulus. The TRH test was performed in all patients and control subjects. We used a single TRH dose of 200 µg, given by intravenous injection. Serum was collected before 15 min. and then at 0', 30', 90', 180'intervals. Serum total T4 was measured by Ria method (Ares Serono Kits, Milan, Italy). Serum free T4 was measured using the lisophase kits (Sclavo, Milan Italy). Reference range were : 0.2 - 3.0 mU/L for TSH; TT4 = 64 - 157 nmol/ml; and FT4 7.7 26 pmol/ml.

Statistical Analysis

Values are presented as mean+/- and Standard Deviation (SD). Statistical analysis was performed by evaluating correlation, using Pearson's linear regression model (SPSS for MS Windows Release 5.0, 1992). A P value of <0.05 was considered significant.

3 RESULTS

In 35 subjects the TT4 and FT4 range serum concentration was at medium low levels compared to normal value (Tab.2). Determinations of TSH (IRMA) were obtained on all subjects. Levels of TSH higher than normal (>3 mU/l) were found in 12 subjects (1.1% of the whole studied population), 9 were women and 3 men (F/M=3/1): six subjects had TT4 values <65 nmol/ml and FT4 <9.5 pg/ml. In 4 subjects TT4 values were between 65 and 80 ng/ml and FT4 between 9.5 and 11 pmol/ml; in other two TT4> 80 nmol/ml and FT4> 11 pmol/ml The inverse correlation between the sensitive thyrotropin and TT4 (r=-.80, P<0.01 in the investigated patients and r=-.27, P<0.03 in the control subjects) was confirmed.TSH showed a gradual increase with progressive thyroid failure. The TSH response to TRH was exaggerated in all these patients. Six of these twelve subjects were started on thyroxine therapy with L-Thyroxine (Eutirox®, Bracco, Italy)) 50µg/die; all had a decrease of TSH and an increase of TT4 and FT4 levels. Thyrotropin values resulted being 2+/-0.8 mU/l and thyroid hormones, TT4 and FT4, were in the normal range. Two out of six untreated subjects had a fall in the thyroid hormone serum concentration and/or a rise in the TSH. In five of these untreated subjects the TRH test confirmed an exaggerated response, typical of hypothyroidism.

Tab. 2-Hormone measurement (mean+/-SD)in 35 studied subjects

	CONTROLS	TSH>3	TSH<3
N° of patients	50	12	23
Age	39,4 (+/-12,9)	45,2 (+/-13,1)	30,6 (+/-6,5)
TT4 (nmol/ml)	131,4 (+/ 10,7)	72,2 (+/ 14,1)	105,9 (+/ 4,5)
FT4 (pmol/ml)	19,1 (+/-2)	9,8 (+/-1,7)	14,2 (+/-1,5)
TSH (mU/L)	1,9 (+/-0,4)	4,7 (+/-0,8)	2,0 (+/- 0,4)
Peak of TSH after TRH	14,5 (+/-2,5)	45,7 (+/-3,9)	17,4 (+/-3,7)

Fig.1- Thyroid hormone production and serum hormone concentration in normal and hypothyroid subjects

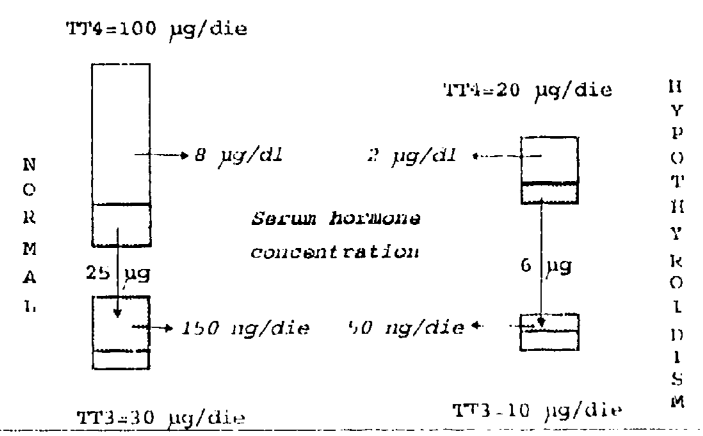
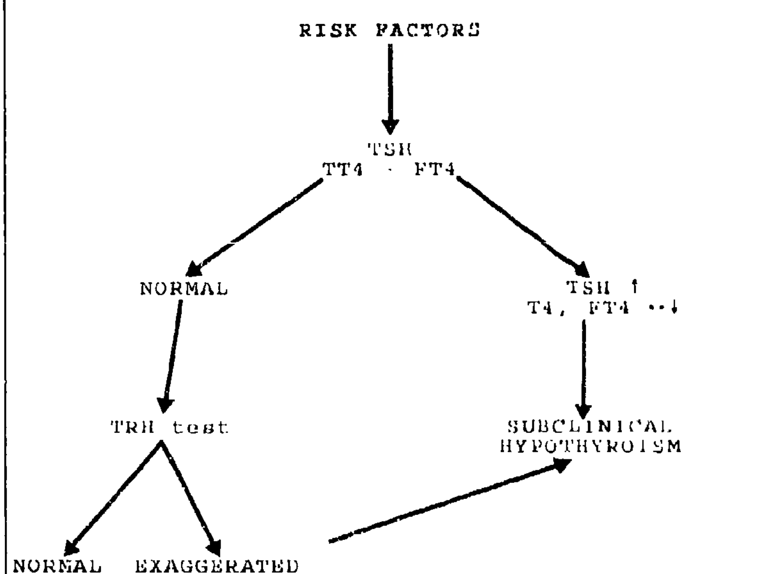


Fig.2-Subclinical hypothyroidism: flow chart



Tab. 3-Population with risk factors for subclinical hypothyroidism

Newborns (birth to 10 wk)
Patients with strong family history of thyroid disease
Elderly patients (over 65 age)
New mothers (4 8 wk postpartum)
Patients with autoimmune disease
Adapted from MARTINEZ M.

DISCUSSION

Hypothyroidism is a disorder characterized by different degrees of thyroid failure, and its metabolic consequences. The production rate of T4 is decreased to about 75 per cent in overt hypothyroidism (Ref [illegible]), whereas, in subclinical hypothyroidism, the increased TSH secretion limits the decline in thyroid hormone production and release (Fig [illegible]). Subclinical hypothyroidism can be considered as a compensated hypothyroidism, with high TSH values (before and/or after TRH administration) and equivocal or slightly low thyroid hormone concentrations (Ref 18). Up to 3% of the population can be placed in this category (Ref 19).

In our [illegible] all subjects were healthy, [illegible] family history [illegible] thyroid disease nor on medication affecting thyroid function.
We were interested in the evaluation of existing correlations between low or [illegible] low thyroid hormone concentration and a borderline function of the thyroid gland in pilots and/or flight personnel.
Every tissue in the body is affected to a greater or lesser extent by thyroid hormone disorders: the skeletal system, the cardiovascular system, metabolism, cognitive and emotional functions may be altered not only in overt hypothyroidism, but also in subclinical hypothyroidism.
An increase of serum TSH is a very early biochemical marker of thyroid failure, resulting from the progressive decrease of T4 (Ref 20).
TSH assay is the primary and the most useful screening test for subclinical hypothyroidism (Fig 2).
[illegible] Beltrani (Ref 8,20) recommend random screening of asymptomatic subjects for thyroid disease in certain high-risk groups only: elderly patients, newborns, new mothers, patients with autoimmune disease or with a strong family history of thyroid disease (Tab 3).
In this study 3.1% of the examined flight personnel had abnormal thyroid hormone blood concentrations and 1.1% showed a biochemical assessment typical of subclinical hypotyroidism. In spite of a low prevalence, the benefits of a screening for subclinical hypothyroidism during selection and successively, at random, during ordinary checkups would be much higher than the costs involved (Ref 21). In some particular situations, as flight, symptoms in subclinical hypothyroidism are evident too. This is probably due to minor O_2 concentration: the reduced delivery of oxigen to tissues using it, at a normal rate, should result in some degree of cerebral hypoxia (Ref 16). The latency of visual evoked potentials is prolonged and electroencephalography shows decreased amplitude and loss of the alpha rhythm (Ref 22).
Monzani et al. demonstrated an early onset of neuropsychological and behavioural disturbances in subclinical hypothyroidism (Ref 23). They used the Wechsler Memory Scale (WMS) (Ref 24) and found that patients with subclinical hypothyroidism had lower efficiency in six out of seven WMS tests. The authors emphasized the presence of alterations, especially in logic memory and spatial and temporal sense of [illegible]ality. There was also a [illegible]ication of behaviour with a [illegible] index of neurosis, evaluated with Crown & Crisp Experimental Index (Ref 25).
These evidences of an impairment of memory and behaviour strengthen the aeromedical interest in subclinical

hypothyroidism and the evaluation that these patients should be treated with adequate doses of L-T4, like in overt hypothyroidism.

Controversy exists over whether or not subjects with subclinical hypothyroidism should be treated (Ref 20). The long term benefits and risks of treatment with levothyroxine have been not extensively studied. Some authors recommended treatment of all patients because overt hypothyroidism develops in a certain number of these patients (Ref 26) to prevent the emergence of clinical disease (Ref 27, 28, 29). The risk for overt hypothyroidism is correlated, in Staub et al., with the grade of thyroid gland disfunction and with the presence or not of the thyroid antibodies and of the thyroid function reserve (Ref 10) with a TSH serum level of 6 mU/l, the calculated risk is about 21% and 59% with TSH > 20 mU/l. Otherwise other authors focus on the risks of treatment, including osteoporosis, cardiac disease or increasing of liver enzyme levels (Ref 30). Petersen et al. did not find elevation in morbidity (myocardial infarction, diabetes mellitus, stroke) or mortality in patients treated with L-T4 (Ref 31). Bogner et al, while agreeing upon the fact that indiscriminate L-thyroxine therapy may be associated with adverse effects, such as bone loss, and should be avoided, suggested that the justification of thyroid hormone replacement in patients with subclinical hypothyroidism should be based on potential adverse consequences of subclinical hypothyroidism (Ref 32). If a patient with subclinical hypothyroidism is not treated he should be followed on a life-long basis in order to detect clinical features of this syndrome. From a practical point of view, it surely is simpler and less expensive to treat subclinical hypothyroidism subjects with small doses of L-T4, that to retest them periodically waiting to hypothyroidism to develop (Ref 21).

5 CONCLUSION

Routine screenig by measuring basal TSH levels is indicated in all patients at risk for developing hypothyroidism (Ref 33).

In order to aid selection and suitability to fly, this screening should be also recommended in aeromedical evaluation, for metabolic changes in peripheral target organs, and especially, for impairment of mental functions and behaviour (Ref 23).

The sensitive TSH assay is the most ideal to this regard, since it has the highest sensitivity and specificity in the diagnosis of thyroid disfunction (Ref 34).

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Tunbridge	1977	2779	0	28 (TSH>5)
Hodkinson	1977	114	17	not given
Sawin	1979	374	32	27 (TSH>10)
Nystrom	1981	1283	0	12 (TSH>6)
Campbell	1981	427	9	not given
Falkenbeg	1983	1442	6	11 (TSH>7)
Brochmann	1988	200	12	24 (TSH>6)
Okamura	1989	2421	4	33 (TSH>4,1)
Present study	1993	1150	0	12 (TSH>3)

Tab. 2-Hormone measurement (mean+/-SD)in 35 studied subjects

	CONTROLS	TSH>3	TSH<3
N° of patients	50	12	23
Age	39,4 (+/-12,9)	45,2 (+/-13,1)	30,6 (+/-6,5)
TT4 (nmol/ml)	131,4 (+/-10,7)	72,2 (+/-14,1)	105,9 (+/-4,5)
FT4 (pmol/ml)	19,1 (+/-2)	9,8 (+/-1,7)	14,2 (+/-1,5)
TSH (mU/L)	1,9 (+/-0,4)	4,7 (+/-0,8)	2,0 (+/- 0,4)
Peak of TSH after TRH	14,5 (+/-2,5)	45,7 (+/-3,9)	17,4 (+/-3,7)

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Tab. 3 - Population with risk factors for subclinical hypothyroidism
Newborns (birth to 10 wk)
Patients with strong family history of thyroid disease
1lderly patients (over 65 age)
New mothers (4-8 wk postpartum)
Patients with autoimmune disease
Adapted from MARTINEZ M.

9-12

Fig.1- Thyroid hormone production and serum hormone concentration in normal and hypothyroid subjects

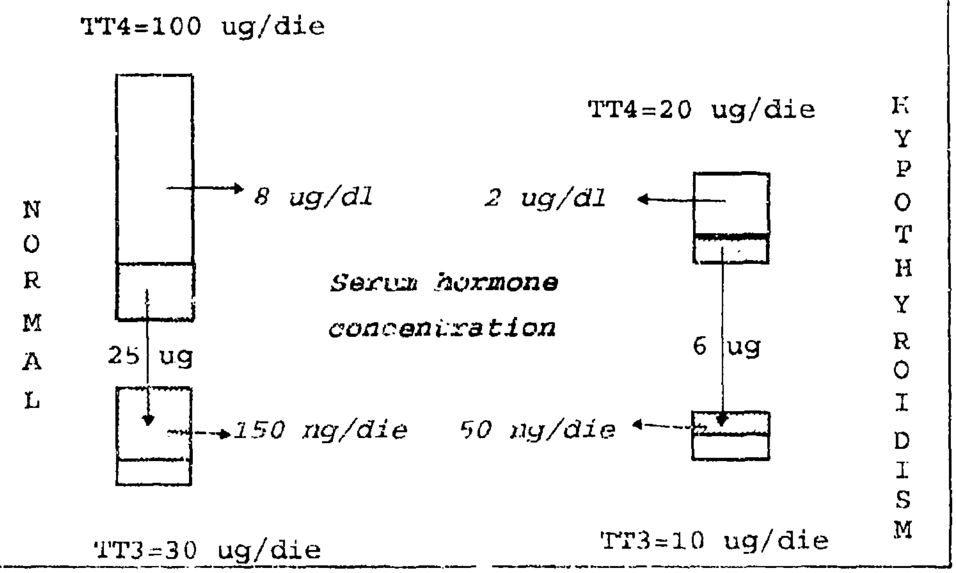
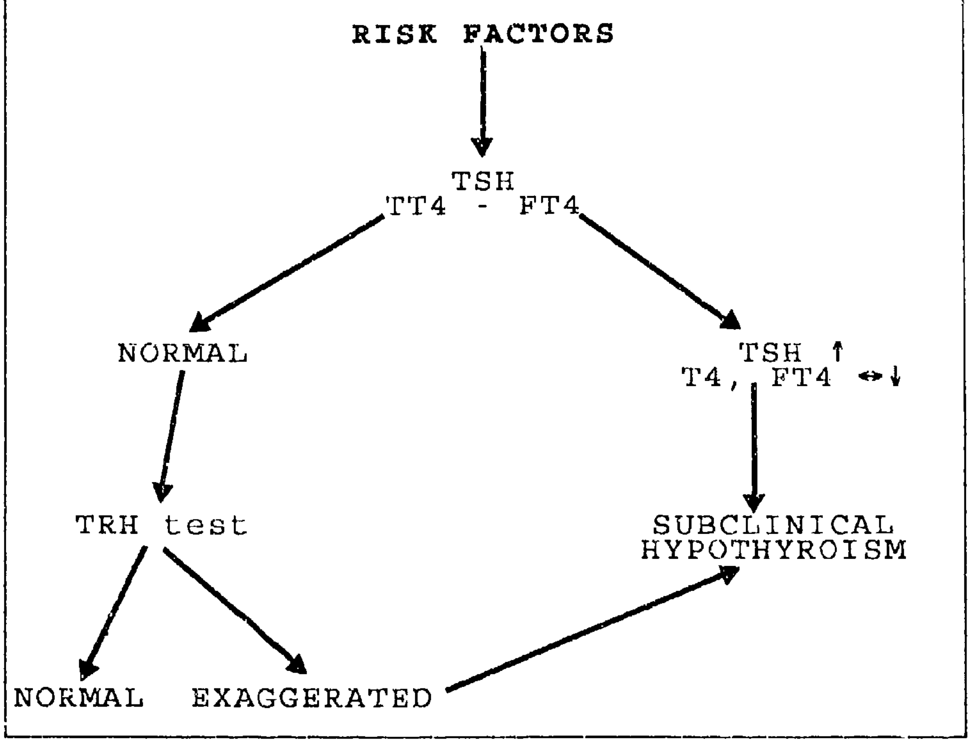


Fig.2-Subclinical hypothyroidism: flow chart



L' ELECTROCARDIOGRAMME EN VOL

INTERET POUR LA REHABILITATION DU PERSONNEL NAVIGANT

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RESUME

Au cours des 16 dernières années, 86 enregistrements ECG en vol ont été réalisés chez des membres du personnel navigant français en vue de déterminer leur aptitude à reprendre les vols. Les pilotes de chasse sont le plus souvent en cause (39%) devant les pilotes d'hélicoptères (27%), les pilotes de transport (13%) et les élèves pilotes (9%). Les indications préférentielles ont été les anomalies ECG et en particulier les troubles de l'excitabilité, il s'agissait plus rarement d'anomalies cardiaques coronariennes ou valvulaires. Cet examen a apporté des éléments favorables à la reprise des vols dans 70%, des éléments négatifs dans 15% et n'était pas suffisamment fondé dans 15%. Cet examen constitue un complément utile aux explorations cardiaques conventionnelles lors de certaines décisions de reprise des vols.

Le système cardio-vasculaire occupe une place privilégiée dans les préoccupations des médecins chargés de la surveillance du personnel navigant. Les moyens de la cardiologie clinique sont très largement utilisés : ECG ambulatoire, ECG d'effort, imagerie échocardiographique et scintigraphique, cathétérisme et coronarographie.

Les exigences professionnelles particulières du pilote nécessitent parfois le recours à des tests plus spécifiques: enregistrement lors d'une montée fictive en altitude dans un caisson à dépression, mise sous accélération grâce à la centrifugeuse.

L'ECG en vol représente un moyen pour tester le comportement cardiaque du pilote en situation opérationnelle. Nous allons vous présenter notre expérience en ce domaine, en dégageant autant que possible la part qu'a pu prendre ce test lors de décisions d'aptitude aux fonctions de personnel navigant.

1. CONDITIONS DE L'ETUDE

Entre 1978 et 1993, des enregistrements en vol ont été effectués chez certains membres du personnel navigant soumis à une expertise médicale en raison d'anomalies variées.

L'enregistrement a porté sur la période de vol mais aussi sur les heures précédant et suivant la mission. Le système d'enregistrement et de lecture était le système distribué en France par la société ELA Médical avec acquisition de 2 pistes ECG. Cet appareillage ne permettant pas d'enregistrer les niveaux d'accélération.

Une étude expérimentale préalable du système avait été entreprise chez plusieurs échantillons de pilotes militaires : pilotes de chasse, de transport, d'hélicoptères, élèves pilotes afin d'évaluer la faisabilité de l'examen. Les exigences techniques en matière de système embarqué ont été respectées, en particulier pour permettre une éventuelle éjection sans risque. Le matériel d'enregistrement avait préalablement été testé en centrifugeuse, les fluctuations de la base de temps étaient inférieures à 5% même pour des niveaux de 10G Z.

2. PRESENTATION DE LA POPULATION

Sur une période de 16 ans, 1 082 membres du personnel navigant français ont été soumis à expertise médicale dans le Service de Médecine Aéronautique de l'Hôpital d'Instruction des Armées Dominique Larrey de Versailles en vue de déterminer leur aptitude à poursuivre leur carrière. Soixante neuf d'entre eux (6 %) ont subi un ou plusieurs ECG durant leur activité aéronautique, soit un total de 86 enregistrements. Seuls 83 de ces enregistrements, qui présentaient des qualités suffisantes à la lecture, ont été étudiés.

La spécialité la plus souvent rencontrée était celle des pilotes de chasse, représentant 39 % de l'ensemble de la population et 40 % des enregistrements. Venaient ensuite les pilotes d'hélicoptère 27 %, les pilotes de transport 13 % et les élèves pilotes 9 %. Deux pilotes seulement étaient des pilotes civils.

La plupart des sujets examinés étaient très expérimentés avec une moyenne d'âge de 35 ans, correspondant à une moyenne de 2 700 heures de vol.

3. RESULTATS

Les observations qui sont rapportées correspondent à un total de 154 heures d'enregistrement en vol soit une durée moyenne de mission de 110 mn.

Les résultats sont présentés après classement des principales indications de l'examen. Le même pilote pouvant présenter plusieurs anomalies justifiant la pratique de l'examen comme par exemple : une extrasystolie ventriculaire associée à des troubles de la repolarisation et un malaise en cours de vol.

Presented at a Symposium on 'The Clinical Basis for Aeromedical Decision Making', April 1994.

Il y a eu 97 indications cumulées de l'examen pour l'ensemble des 83 enregistrements. Ces indications étaient :

- 60 fois des anomalies ECG rencontrées lors d'examens systématiques
- 24 fois des pathologies cardiaques, réelles ou suspectées
- 7 fois des malaises en vol
- 6 fois des problèmes variés

Comme on peut l'observer, les problèmes ECG représentant près de 2/3 des indications, étaient très prédominants (Tableau 1).

LES ANOMALIES ECG

Les extrasystoles ont donné lieu à 28 enregistrements pour 22 pilotes. Il s'agissait d'extrasystoles supraventriculaires pour 6 d'entre eux, dont 1 avec des salves brèves. Sur les 17 sujets présentant des extrasystoles ventriculaires, 2 montraient des épisodes de salves brèves.

Ces extrasystoles s'associaient à une anomalie cardiaque dans 4 cas.

Durant les missions enregistrées, la fréquence des troubles du rythme a été réduite dans 10 cas et augmentée dans 2 cas.

En définitive tous les pilotes de cette catégorie ont pu poursuivre une activité aéronautique sous condition d'un suivi régulier par un cardiologue.

Une tachycardie supraventriculaire a été l'indication de l'examen pour 8 enregistrements soit 7 pilotes. Pour l'un d'entre eux il s'agissait de tachycardie par rythme réciproque, dans 2 cas de tachycardie atriale et dans 4 cas de fibrillation auriculaire paroxystique. Aucune de ces anomalies n'était présente au moment de la mise en place de l'enregistreur. Durant les vols on a pu enregistrer un épisode d'extrasystole supraventriculaire et un épisode de fibrillation auriculaire, alors qu'aucune anomalie n'était notée dans les 5 derniers cas.

Un des pilotes a été déclaré inapte au vol, et pour les autres il a été imposé une substantielle réduction de leur activité, souvent avec un traitement.

Les anomalies de conduction ont été le motif de l'examen pour 16 enregistrements soit 15 pilotes. Il s'agissait de 6 blocs auriculo ventriculaires intermittents, l'un seulement du 1er degré et les 5 autres associés à des périodes de Lucciani Wenckebach. Ces épisodes se sont reproduits en vol dans 2 cas sans qu'on ait noté de bloc de plus haut degré.

Sept blocs de branche étaient en cause dont l'un intermittent qui s'est reproduit au cours du vol. Aucune autre anomalie ECG n'a par ailleurs été enregistrée.

Deux pilotes présentaient des dysfonctions sinusales marquées, asymptomatiques, sans aucune majoration au cours du vol. Ces 15 personnels ont été maintenus en activité mais parfois avec de fortes réductions

Les syndromes de préexcitation ventriculaire ont été le motif de l'examen pour 7 enregistrements, soit 5 personnels navigants. Dans tous les cas il s'agissait d'anomalies asymptomatiques ; il n'y avait dans aucun cas des arguments pour une période réfractaire courte. Dans un cas, réalisé chez un mécanicien navigant d'hélicoptère, avec préexcitation intermittente, l'enregistrement en vol a montré la réapparition de l'anomalie à l'occasion d'une tachycardie sinusale à 150/mn, alors que pendant l'effort cet aspect avait disparu dès le palier 130/mn et ce jusqu'à la fin de l'effort pour une fréquence de 170/mn.

Compte tenu des conditions d'emploi et des données du suivi, l'aptitude avec restriction a été maintenue dans ce cas, ainsi que pour les 4 autres personnels. Une surveillance cardiologique précise a été une des conditions de ce maintien.

Dans un seul cas, **une anomalie de repolarisation** confirmée lors de l'épreuve d'effort a été retenue comme indication. Durant le vol, aucune modification significative de l'ECG n'a été notée.

LES PATHOLOGIES CARDIAQUES

Des pathologies cardiaques, toujours d'importance modérée, ont été le motif de l'examen dans 24 cas. Il s'agissait essentiellement **d'anomalies coronariennes** chez 5 pilotes dont 3 cas de suivi post infarctus qui ont justifié 8 enregistrements. L'absence de modifications électrocardiographiques (troubles de la repolarisation ou de l'excitabilité) a été vérifiée pendant les différentes périodes de vol et les heures qui ont précédé et suivi les missions. Chez les 2 autres pilotes, il s'est agi d'un contrôle à distance d'un pontage coronarien et d'une angioplastie.

Les résultats de l'ensemble des examens ont permis le maintien de l'aptitude avec des restrictions importantes.

Des anomalies valvulaires ont été en cause chez 6 pilotes pour 8 enregistrements. Il s'agissait de 3 cas d'insuffisance aortique modérée sans retentissement ventriculaire gauche, d'une insuffisance mitrale modérée, d'un prolapsus valvulaire mitral et d'une ballonisation mitrale. Dans un cas, il s'y associait une extrasystolie ventriculaire.

Sur tous les enregistrements en vol, aucun trouble significatif de l'excitabilité n'a été enregistré.

Trois pilotes ont été enregistrés pour **hypertension artérielle**, afin de vérifier la tolérance en vol de leur traitement. Chez 2 de ces pilotes, il existait par ailleurs des troubles de l'excitabilité. Dans tous les cas, dont 2 pilotes de chasse, les enregistrements ont été tout à fait satisfaisants.

Enfin, un pilote de chasse était porteur **d'une hypertrophie septale** modérée sans obstruction, associée à une extrasystolie supraventriculaire isolée, qui a persisté au cours du vol.

LES MALAISES EN VOL

Des indications ont été posées dans le cadre de l'enquête pour malaises en vol chez 7 pilotes, 2 pilotes de chasse confirmés et 5 élèves.

Dans 5 cas était survenue une perte de connaissance sous accélération. Chez 3 pilotes, la survenue, lors du test, d'une tachycardie sinusale anormale en vol s'est accompagnée d'une décision d'inaptitude définitive aux emplois du personnel navigant.

DIVERS

Enfin, on peut signaler 5 enregistrements effectués pour lipothymie survenue au sol dont 2 cas en association avec une fibrillation auriculaire. Enfin 1 pilote d'hélicoptère a été enregistré alors qu'il était porteur d'une sacroïléite.

4. LIMITATIONS TECHNIQUES

Les difficultés techniques liées à ce type d'examen ne doivent cependant pas être méconnues. Elles tiennent tout d'abord à la sécurité aérienne car il s'agit d'enregistrer un pilote qui ne présente pas toutes les garanties d'intégrité physiologique au moment du vol. Il est donc souhaitable que le vol-test soit effectué sur un aéronef avec double commande qui soit aussi proche que possible de celui utilisé habituellement par l'intéressé. Cette nécessité peut être source de difficultés dans le cas des pilotes de chasse. Le déroulement même de la mission-test peut évidemment poser également des problèmes compte tenu des impératifs opérationnels, météorologiques, etc.

D'autre part, il convient de faire en sorte que les contraintes subies au cours de cette mission, soient aussi proches que possible de celles rencontrées par l'intéressé dans son exercice habituel. On peut évidemment penser que le sujet testé bénéficiera d'une certaine "protection" de la part du co-pilote. Il est bien rare que le niveau d'accélération maxima déclaré soit équivalent à celui que l'on peut obtenir facilement au cours des tests en centrifugeuse.

La qualité du tracé doit être suffisamment bonne pour que l'on puisse effectuer une analyse correcte de la phase de vol qui est celle où le risque de parasitage est maximum.

Nous n'avons eu à rejeter que 3 enregistrements sur 86 et il nous parait démontré que la mise en place de l'appareil par une équipe relativement rodée à la technique, s'accompagne de très bons résultats souvent supérieurs à ceux observés en centrifugeuse. Les seules déconvenues ont été observées lorsque, pour des raisons pratiques, la pose de l'enregistreur avait été faite en dehors du Service.

Une bonne interprétation des résultats observés ne peut, à notre avis, se faire sans connaitre le retentissement sur l'ECG des différents types de stress aéronautique. Cette connaissance suppose une expérience suffisante acquise grâce à l'enregistrement de personnels navigants réputés sains.

5. INTERET DE LA METHODE

Dans ce travail, dont nous ne connaissons pas d'équivalent dans la littérature, nous avons voulu dresser un bilan rétrospectif de notre expérience et, en particulier, évaluer la contribution de l'examen à la prise de décision d'aptitude. Il est bien évident qu'il s'agit là d'un argument et seulement d'un argument au milieu de bien d'autres.

Dans 70 % des cas, on a effectivement tiré de cet examen des éléments favorables à la reprise d'une activité aéronautique, soit normale, soit avec limitations. Dans 15 %, au contraire, il s'agissait d'une information en faveur d'une décision d'inaptitude. Pour 15 % des tests, l'indication de l'examen n'est pas apparue suffisamment fondée.

On peut remarquer que pour certains pilotes de chasse, cet examen a été effectué pour remplacer un test en centrifugeuse. Dans d'autres cas, les deux tests ont été effectués successivement, habituellement le test en vol après celui en centrifugeuse.

A notre avis, le holter en vol est particulièrement bien indiqué dans le cas du pilote de chasse, car la diversité des contraintes est mieux reproduite que dans un test en centrifugeuse.

Les informations les plus contributives concernent préférentiellement 3 types d'anomalies ECG :

- l'extrasystolie ventriculaire où l'ECG en vol a été réalisé chez 30 % des pilotes examinés pour ce type d'anomalie.

- la fibrillation auriculaire paroxystique où l'ECG en vol a été réalisé dans 28 % des cas.

- les syndromes de préexcitation où il a été réalisé dans 62 % des cas (Tableau 2)

Nous tirons parfois souvent des arguments de cet examen pour prendre une décision de reprise d'activité, après des incidents survenus au cours d'un vol. L'examen n'a cependant été effectué que dans 6 % des 117 cas soumis à expertise dans le Service.

Cet examen ne saurait en aucun cas se substituer aux examens invasifs de la cardiologie moderne. Il ne trouve sa place qu'à la suite de bon nombre d'explorations cardiologiques traditionnelles. Il n'est pas indiqué si une décision d'inaptitude doit être prise à l'issue de ces explorations. Ce test vient le plus souvent comme argument pour conforter une décision de maintien d'aptitude en précisant au mieux l'adaptation du système nerveux végétatif du pilote à son milieu et à sa fonction

	Extrasystolie	Tachycardie supra-ventriculaire	Trouble de conduction	Préexcitation	Coronaropathie	Valvulopathie	Malaise en vol
Pilote de chasse	13	1	6	2	1	4	2
Pilote hélicoptère	5	3	4	2	1	3	0
Pilote transport	2	2	3	0	2	0	0
Elève pilote	1	0	1	0	0	0	5
Mécanicien	1	1	1	1	1	0	0
Pilote civil	0	0	0	0	2	0	0
TOTAL	22	7	15	5	7	7	7

Principales indications par catégorie de personnel navigant.

Tableau1

INDICATIONS	Nombre de sujets explorés en 16 ans	Réalisation de l'ECG en vol
Extrasystolie ventriculaire	58	30%
Bloc de branche	27	30%
Bloc auriculoventriculaire	15	40%
Fibrillation auriculaire	14	28%
Préexcitation	8	62%
Malaise en vol	117	06%

Problèmes d'expertise et ECG en vol

Tableau 2

EKG IN FLIGHT
USEFULNESS AND LIMITS FOR AIRCREW REHABILITATION

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SUMMARY

During the last 16 years, we have performed 86 in-flight EKG's on french aircrew members in order to have additional arguments for fitness decisions. Fighter pilots were the most important group (39%) followed by helicopter pilots (27%), transport pilots (13%) and student pilots (9%). The most important reasons were EKG disturbances and in particular excitability disorders. Cardiac troubles like coronary or valvular disease were rarer. This examination provided positive indication of flying fitness in 70% of cases, negative indications in 15% and no indication in 15% of cases. It is a useful complement to conventional cardiac investigations before medical decision in certain cases (6.3%).

The cardiovascular system is one of the major preoccupations of the physicians responsible for aircrew medical examinations. Clinical cardiology methods and equipments are widely used: ambulatory EKG, exercise EKG, echocardiographic and scintigraphic imaging, catheterism and coronarography.

The special occupational environments of aircrew sometimes require the use of more specific tests, such as recording simulated ascent in a decompression chamber or exposure to acceleration in a centrifuge.

In-flight EKG provides information on the pilot's cardiac response in operational situations. We should like to describe our experience on this subject.

1. INVESTIGATION CONDITIONS

Between 1978 and 1993, a number of recordings were made in-flight on aircrew submitted to medical examinations because of various medical problems.

The recordings were obtained in-flight, but began a few hours before flight and extended several hours after. We used one of the commercial recording and reading systems available in France, based on the Holter technique.

The system had first been tested on several types of military aircrew: fighter, transport and helicopter pilots, in order to test the feasibility of the examination. Technical requirements for on-board systems were complied with, especially regarding the need to allow the pilot to eject safely from his aircraft. The recording equipment had first been tested in a centrifuge.

2. TEST POPULATION

Over a period of sixteen years, 1082 french aircrew have been submitted to medical examination in the department of Aviation Medicine at the military Hospital Dominique Larrey in Versailles, in order to evaluate their fitness for further flying status. Sixty eight of them (6,3%) underwent one or several EKG examinations during their flying activity, making a total of 86 recordings. Only 83 recordings presenting sufficient criteria for interpretation were studied. The most prevalent specialty was that of fighter pilot with 39% of the population and 40% of all recordings. Helicopter pilots accounted for 27% of the population, transport pilots for 13% and student pilots for 9%. Two of the pilots were from civil aviation.

Presented at a Symposium on 'The Clinical Basis for Aeromedical Decision Making', April 1994

Most examinees were very experienced aircrew with a mean age of 35 years and 2700 flight hours.

3. RESULTS

The reported observations were made over a total of 154 hours of in-flight recording corresponding to mean mission durations of 110 minutes.

Results are presented after classification of the main indications of the examination. The same pilot could be examined for several reasons, for example: premature beats and repolarisation disorders or mild in-flight incapacitation.

There were 97 cumulated indications of this test for all 83 recordings. These indications were:

- EKG disorders: 60 times (62%)
- cardiac disease in 24 cases (25%)
- in-flight malaise in 7 cases (7%)
- various problems in 6 cases (6%)

Electrocardiographic problems are clearly prevalent, they account for 62% of the 97 indications. (Table 1).

EKG DISORDERS

Premature beats were the cause of 28 recordings obtained from 22 pilots. They were supraventricular beats in 6 cases, one with salvos. Of the 22 subjects who exhibited ventricular premature beats, 2 showed brief salvos.

In 4 cases out of the 22, they were associated with an underlying pathology.

During the flight period, the frequency of rhythm disorders was reduced in 10 of the recordings, but increased in 2.

Finally all pilots were declared fit on the condition that they would report regularly for medical examination by a specialist.

Supraventricular tachycardias were the cause of 8 recordings obtained from 7 pilots. One was a case of reciprocal tachycardia, there were 2 cases of atrial tachycardia and 4 cases of paroxysmal atrial fibrillation. All these disorders were not present when the recorders were placed on the aircrew. Observation during the flight showed one event of supraventricular premature beats and one episode of atrial fibrillation although no anomaly was recorded in the last 5 cases.

One pilot was declared unfit and the others were told to substantially reduce their activity, often with treatment.

Conduction disorders were the cause of 16 recordings obtained from 15 aircrew:

- Six intermittent atrioventricular blocks, one first degree block and 5 others with associated Lucciani Wenckebach episodes. These episodes occurred in-flight in 2 cases with no observation of blocks of a higher degree.
- Seven branch blocks were studied, one intermittent block was observed again during flight. No electrocardiographic anomaly was other wise reported.
- Two pilots were recorded for asymptomatic sinus dysfunction and showed no worsening of the EKG during the flight recording.

All 15 pilots were re qualified but sometimes with restriction in their flying activity.

Ventricular preexcitation was the cause of 7 recordings corresponding to 5 aircrew. These disorders were asymptomatic in all cases. No accessory pathway with short refractory period was observed in any of the cases. For one helicopter flight engineer we observed that intermittent preexcitation disappeared at 130 beats/mn and did not recur until the end of a stress test at 170 beats/mn; but in flight, the preexcitation wave reappeared during an episode of 150 beats/mn sinus tachycardia. In view of the specialty of this engineer and the results of long term observation, we decided to maintain restricted activity, as we did for the others, with a waiver.

A cardiological survey was one of the conditions for the requalification.

Only one case of repolarisation trouble confirmed during in-flight EKG was found. During the flight, we did not observed any EKG anomaly.

CARDIAC DISEASES

Coronary troubles were the cause of 24 in-flight EKG's for 5 pilots. For 3 pilots, this was a post infarct survey requiring 8 recordings. We wanted to confirm the absence of EKG change during the different flight periods and also during the hours preceding and following these flights.

For the 2 other pilots, there was remote monitoring of a coronary by pass and an angioplasty.

Following these tests, fitness to fly was maintained but with important restrictions in activity.

Valvular diseases were the cause of 8 recordings for 6 pilots. In 3 cases there was minor aortic insufficiency without left ventricular enlargement, 1 case of minor mitral insuffiency, 1 case of mitral prolapse and 1 mitral leaflet billowing. In one case the pilot also had ventricular ectopic beats. No major excitability trouble was observed on any of the in-flight recordings.

Hypertension was the cause of recordings for 3 pilots, to test in-flight tolerance of the drugs needed to treat this disease. In 2 of them, there were also ectopic beats. In all cases including 2 fighter pilots, recording were completely satisfactory.

A minor septal hypertrophy without left ventricular obstruction was found in 1 fighter pilot. It was associated with supraventricular ectopic activity, which persisted throughout the flight.

IN-FLIGHT MALAISES

For 7 pilots comprising 2 fighter pilots and 5 student pilots, the test was performed as part of the investigation of troubles that appeared during flight activity. In 5 cases it was G LOC. In 3 cases (during the test) abnormal sinus tachycardia appeared and we decided to ground all of them.

Finally, 5 recordings were made, following fainting on return from flying. In 2 cases this was atrial fibrillation.

One helicopter pilot was recorded with an articular disease.

4. TECHNICAL PROBLEMS

These recordings were hampered by certain technical problems which should not be overlooked.

First, the problem of flight safety in the case of a pilot tested to verify that he still flies with the same professional skills as before. In this case, the flight test should be performed in an aircraft as similar as possible to the one usually flown by the pilot; the test requires a copilot. These requirements may create a problem for fighter pilots.

The test mission itself may sometimes encounter problems associated with operational requirements, weather conditions.....

One should also make sure that these characteristics are as close as possible to the usual working conditions experienced by the pilots. The copilot may sometimes tend to "protect" the pilot. Seldom does the reported acceleration level really correspond to the maximum tolerance level such as can be obtained in a centrifuge.

The quality of the recording should be good enough to be able to determine which phase of the flight is most likely to show interference.

We had to reject only 3 recordings out of 86 and our experience shows that installation of the recording system by a team relatively familiar with the technique produces very good results. Problems were only been observed when the recording system has been installed by people from outside our department.

Finally, to interpret results, one has to know the usual conditions of cardiac adaptation to the various types of aviation stress. Such knowledge can only be derived from observations made on healthy aircrew.

5. USEFULNESS OF THIS TEST

We do not know any equivalent of this work, whose aim is to show the contribution to decision making in the case of aircrew with flying fitness problems. It is clear that this test is only one argument among many.

This retrospective study shows that it was a positive argument for rehabilitation in 70% of all cases; often by means of a waiver. In 15% it was a negative indication leading to grounding.

For the last 15%, it appears that it was not a good indication.

For several reasons (technical possibilities for example) this was performed instead a centrifuge test. In other cases, the two tests were performed one after the other; usually the in-flight test after the centrifuge test.

In our opinion, in-flight EKG is most efficient for fighter pilots because the different types of flight constraints are better reproduced in an aircraft than by a centrifuge test.

We found that the greatest contribution of this special EKG mostly concerns ventricular premature beats. In these cases, in-flight EKG was performed on 30% of pilots exhibiting excitability trouble. Paroxystic atrial fibrillation was also a good indication and the in-flight test was performed in 28% of all cases. For pre-excitation syndromes, it was performed in 62% of 8 cases. (table 2)

Sometimes it is also possible to make a case for a decision after an in-flight human incident. However, the test was performed in 6% only of the 117 cases that were examined by our service.

This test cannot be considered in any way of a replacement for the major invasive tests of modern cardiology and it has its place only after the other examinations of traditional cardiology. It should not be considered if they lead to a grounding decision.

It is a functional test for confirmation of a flying fitness decision, providing detailed information on the adaptation of the pilot's autonomous nervous system to his environment and his function.

	Extrasystole	Supra ventricular tachycardia	Conduction troubles	Pre-excitation	Coronaropathy	Valvulopathy	in Flight illness
Fighter pilots	13	1	6	2	1	4	2
Helicopter pilots	5	3	4	2	1	3	0
Transport pilots	2	2	3	0	2	0	0
Student pilots	1	0	1	0	0	0	5
Flight Engineer	1	1	1	1	1	0	0
Civilian pilots	0	0	0	0	2	0	0
TOTAL	22	7	15	5	7	7	7

Main indication per type of aircrew

Table 1

INDICATIONS	Total examination in 16 years	Performance of in-flight EKG
Ventricular premature beat	58	30%
Bundle branch block	27	30%
Atrio-ventricular block	15	40%
Atrial fibrillation	14	28%
Pre-excitation	8	62%
In-flight malaise	117	6%

Flight fitness examinations and in-flight EKG

Table 2

EVALUATION OF THE EKG's ISOELECTRIC T WAVE IN AIR FORCE PILOTS

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ABSTRACT:

171 out of 5126 performed EKG from aircrew members (3.33%), showed some ST-T wave abnormalities.

We studied 23 out of 171 with isoelectric (low amplitude or moderate inversion, but less than 1 mm) in all leads but not in V2-V3 where T wave were normal. Six of those, had T wave inversión in III and avF leads. All of 23 are healthy males, betwen 30-55 years old (43.6±7.3), without associated EKG dissorders, ionics alterations, and no one regulary practice heavy exercise.

Each one had between 3 and 21 (11.5±6.5) EKG recorders along a following period of 3 to 20 years (13.0±6.3). All of they has been evaluated through treadmill test (Bruce protocol, submaximal>90%), Doppler-Echocardiography and 24 hours Holter monitoring.

We found in 22 cases (95.6%), echocardiographic criteria of left ventricular hypertrophy (IV septum more than 13 mm). 15 out of 15 were simetric and 6 were asimetric. 19 cases (86.4%) had a mitral filling flow pattern tipical of left ventricular compliance disorder, with atrial wave (A) bigger than fast filling wave (E). Only 3 cases (13.6%) had normal mitral flow doppler pattern. Valvular or subvalvular aortic gradient was not found in any case.

Bruce test were negative in all cases, but in 21 of those (91.3%), during exercise or the first minute of recovery, T waves became normals, returning to be isoelectrics before 10 minutes.

We conclude that asymptomatic flyers without coronary risk factors with isoelectric T waves in all EKG leads (but normals T waves in V2-V3), with or without T inversion in III and avF leads, should be adequately tested in order to rule-out mild hypertrophic myocardiopathy, by Doppler-Echocardiography, and do not focus our attention triyng to found coronay artery disease.

INTRODUCTION:

Electrocardiography (EKG) is a requirement for routine cardiovascular evaluation. T waves changes, are the most common finding in EKG. EKG performed in asymptomatic healthy people has limitations due to their lack of especificity. In Aircrews members these EKG' abnormalities could lead to discussion and to a wide spectrum of assesing considerations. This problem is specially complex when the subject is a pilot and even more if he flies high performance aircrafts. In these cases hypoxia, high Gz's and stress could be an additional factor to consider in non detected cardiovascular disorders.

Many cardiovascular diseases have been described as leading factors to produce isoelectric T-Waves. Very often they are a consequence of endocrino-metabolic diseases, ionic disorders or pharmachological effects. Sometimes, as a single manifestation or, together with other EKG changes, T-wave changes might be meaningful data of underlying heart diseases. Veery often isoelectric T-Waves appear in healthy people due to anxiety, digestion, tobacco or by no apparent reasons (1,2). Obviously, before considering those findings as non-significant, aviators must undergo a detailed cardiological exam in order to rule-out any cardiological contributor to decreasing flight safety.

In our experience it is often to find along the routine EKG exam, a isoelectrical T-Wave in every lead except V2-V3, and we observed that these EKG patterns are frequently associated with specific findings in echocardiograms (ECHO), cardiac doppler and exercise test (ET).

METHOD:

For selection purposes, we have reviewed the EKG's of 5126 aircrew members, who undergo their periodical medical exam along 1993. We found isoelectric T-Waves in 171 of them. In 45 cases (0.88%) t-wave was isoelectric in every lead except V1-V2 (Figure 1). In addition 12 of these had a negatives T-waves in III and aVF leads (fig 2).

Exclusion criteria were based on the diagnosis of hypertension, daily practice of athletic exercise, metabolic disorders, drug abuse or inadequate ultrasonic window. The study finally was carried out in 23 subjects.

Each case had been followed up, since his initial exam by reviewing a minimum of 3 EKG and a maximum of 21 in a period of time between 3 to 20 years (13.0±6.3). All examinees were males and aged between 30 and 55 (43.6±7.3).

Treadmill exercise test, ECHO-Doppler and 24 hours Holter monitoring was performed in all cases. A control group of 15 healthy subjects, with same age range (41.5±7.3) was studied with the similar protocol.

None of these 38 cases (both groups included), following the Sokolow-Lyon criteria for left ventricular hypertrofia, had low potentials (3) nor QRS axis below 0º or above 90º. In those subjects with isoelectric T-wave, EKG was repited without previous intake of food, coffee drinks or smoking. Other EKG was performed after 30 segs of hyperventilation.

ECHO-Doppler recordings were performed using a TOSHIBA SSH-160 A device with 3.75 and 2.5 Mhz phase array transducers. Recorders supplies enough quality to correctly identify the endocardial limits. Meassurements was made

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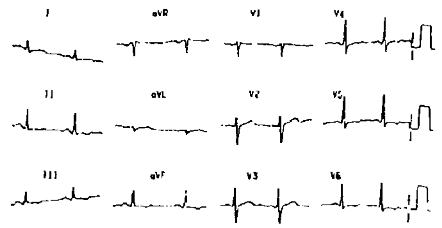


Figure 1:

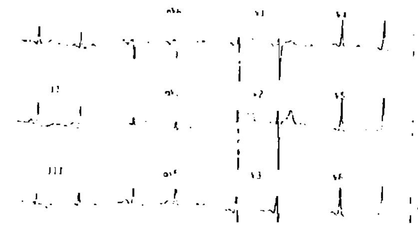


Figure 2:

from M-mode recorders obtained under bidimensional control, following the requirements of the American Society of Echocardiography (4).

Left ventricular end-diastolic (LVDV) and end-systolic (LVSV) volumes, and ejection fraction (EF) was automatically obtained from the M-Mode measurements by using the Teicholz Formula (5). We estudied the extent and distribution of LV hypertrophy by two-dimensional procedure in the parasternal log-axis and short-axis, and in the apical 4 and 2 chamber views. Pericarditis, valvular disease, and regional contractility disorders was ruled-out. Assimetry, was considered when the ratio between each of two left ventricular wall thickness was above 1.3.(6)

LV mass was calculated following the Troy Formula: LV mass= $1.05\{(IVSWT+LVIDd+PWT)^3-LVIDd^3\}$ grams, (when IVSWT: interventricular septal wall thickness, LVIDd: LV internal end-diastolic diameter, and PWT: LV posterio wall thickness), based in ASE criteria.(7) , Correspondant indexes related to body surface area, obtained from height and weight (8), were calculated from LV volumes and mass.

We used Color-Flow Doppler technique to rule-out valvular regurgitación. Pulsed Doppler recordings of diastolic transmitral flow velocity profiles were recorded with the sample volume located at the tips of the mitral leaflets from the apical 4-chambers view.

Flow velocities were not corrected for angle deviation, but care was taken to align the sample volume as perpendicular to the mitral anulus as posible. From mitral flow we calculed the early-diastolic peak velocity (E-wave), the late-diastolic peak velocity (A-wave), and the ratio between them. Continous Doppler was used for aortic peak flow meassurements.

Exercise test (ET) was performed with a QUINTON 5000 device following Bruce's protocol. 12 conventional leads were recorded being valuable when 90% of the maximal heart rate (220-age) was reached. Arterial pressure was registered with COLIN ST BP-680 automatic equipment at the beggining of the test and each 1.5 minutes. EKG records was obtained at the end of each minute of exercise and in the recovery minutes 1,3,5,7 and 10. We considered the test electrically positive when a ST slope of 1 mm or more at 80 Msecs of J point occurred. We measured T wave height in V5 lead, at rest and at the end of each exercise and recovery steps.

24 hours Holter monitoring was performed in each patient using CARDIOLINE LP-300 magnetic memorie recorders. Analisys of data were performed with a CARDIOLINE AD 24-Plus device.

Data were expressed as mean values ± SD. In control group, range limits was obtained as mean value ± 1.96 SD. Differences between means were assessed by the unpaired Student' test. P value <0.05 was considered to indicate statistical significance.

RESULTS:

45 (0.88%) out of 5126 reviewed cases, had EKG's according to the described pattern. 12 out of then had, in addition, negatives T-waves in III and aVF leads.

We did not find significatives differences in ages, body surface areas, QRS axis, nor QRS voltage, between control and abnormal T-wave group.(Table I)

Table II shows the Eco-Doppler meassurements of the control group, and the normal limits for each the parameters.

Data related to each one of 23 studied subjects with isoelectric T-wave are showed in Table III.

The age of subjects when first isoelectric T-wave EKG was recorded ranged between 21 and 43. Only five cases (signed with a * in table III) this EKG pattern was present in his first EKG we performed. The other cases have previous normal EKG records. Negative T-wave in III and aVF leads, were present in all records from the first exam.

We observed in 13 cases, T-wave diferences between succesive records, appearing some times slightly negatives, slightly positives or normals. We observed that negative T-wave appear commonly when sportive activity had been increased. Conversely, after reducing exercise level, T waves come back to be positives. (figure 3,

In our normal group, the higher LV mass range limit was 128.82 g/m² and, as a consequence of that, 22 out of the 23 cases (95.6%) would have LV hypertrophy, but we used the limit of 150 g/m² admited by several autors (7) for the Troy method. We have considered LV increased mass in 15 out of the 23 cases (68.2%)

These 15 cases had LVSWT of 13 or more mm, and Mitral Flow Doppler E/A ratio less than 1.1, showing decreased LV compliance.

A small LV chamber (with LVEDV less than 44.46 ml) was found in one of this 13 cases and in other 5 cases. In all these cases IVSWT measurement had, at least, 13 mm, and LV compliance was decreased.

According with this data, we considered clearly the diagnosis of hypertrophic cardiomiopathy (HCM) in 20 (87%) out of the 23 cases with isoelectric T-wave. All of them have normal systolic function (EF>51), IVSWT of 13 mm or more, with LV mass >150 g/m² or

with small LV chamber and compliance decreased (Table III). Only 3 cases could not be included. Two of these cases (number 8 and 11), had low EF and do not fulfill the other criteria, because of that they could held other patholog.cal status. In the case number 8 ET was false positive (Talium-201

TABLE I: AGE, BODY SURFACE AREA AND EKGs MEASUREMENTS IN CONTROL GROUP AND IN SUBJECTS WITH ISOELECTRIC T-WAVE

	CONTROL	ABNORMAL T-Wave	p
Age	41.47 ± 7.32	43.67 ± 7.27	NS
BSA	1.89 ± 0.13	1.89 ± 0.08	NS
QRS°	54.60 ± 27.79	49.91 ± 19.86	NS
I+II+III	27.47 ± 5.07	23.04 ± 5.20	NS
SV1+RV5-6	27.27 ± 5.57	23.43 ± 4.40	NS
	(n=15)	(n=23)	

BSA: Body Surface Area (m^2). QRS°: QRS axe angle in frontal plane. I+II+III: QRS total voltaje in these leads. SV1+RV5-6: V1 Lead S wave voltaje add to the biggest R waves in V5 or V6 lead. p: statistical probability. NS: non significative. (Date are given as Mean Values ± Standard Desviation).

TABLE II: ECO DOPPLER MEASUREMENTS IN THE CONTROL GROUP

	$\bar{x}$	±DE	min.	máx.
Aorta	29.30	3.58	22.28	36.33
LA	31.13	3.16	24.93	37.32
LVSWT	9.36	0.87	7.65	11.06
LVPWT	8.68	0.79	7.13	10.22
LVIDd	49.58	3.43	42.85	56.30
EF	64.40	6.83	51.01	77.78
LVEDV/m^2	62.20	8.04	46.44	77.95
LV mass/m^2	103.62	12.86	78.41	128.82
Peak E	80.55	16.71	47.80	113.30
Peak A	46.31	11.68	23.42	69.20
E/A ratio	1.74	0.32	1.11	2.37
Peak Ao	106.60	13.65	79.84	133.35
			(n=15)	

LA: Left atrium (mm). LVSWT: Left ventricular septal wall thickness (mm). LVPWT: Left ventricular posterior wall thickness (mm). LVIDd. Left ventricular internal diastolic diameter. EF: Ejection fraction (%) LVEDV/m^2: Left ventricular end-diastolic volume index, related to body surface area (ml/m^2). LV mass/m^2: Le . ventricular mass index (g/m^2). Peak E: Peak early diastolic filling velocity (cm/seg). Peak A: Peak late diastolic filling velocity (cm/seg). E/A ratio: Ratio between transmitral flow doppler early an late peak diastolic waves. Peak Ao: Peak transaortic flow velocity (cm/seg). x: mean values. SD: Standard desviation. min.-max.: normal range limit values (x±1.96SD).

TABLE III: DATA IN EACH SUBJECT WITH ISOELECTRIC T WAVE

	nº	age	ITW age	LVmass g/m^2	E/A ratio	EXER TEST	SWT	EF	LVEDV ml/m^2	distrib LV mass	NEG T III-F	SAM	ASC	HQS	VPC 24h
	1	37	33*	136.8	1.05	-E	13.1	81	46.4	SYMMETRIC		+			0
	2	43	23	160.6	0.78	-R	13.6	70	60.4	SA					0
	3	33	27	183.8	1.87	-E	13.5	70	55.3	SA-MV-AP		+		+	0
	4	45	28	141.0	0.89	-E	14.0	75	44.0	SYMMETRIC					2
	5	48	28	192.8	0.72	-E	14.0	86	59.4	SYMMETRIC		+			34
	6	50	36	208.3	0.89	-E	15.0	64	65.0	SA-MV-AP-RV	+				12
H	7	32	22	162.6	1.79	-R	13.9	65	63.2	SYMMETRIC	+				0
C	9	48	29	188.5	0.82	-	13.0	64	42.8	SYMMETRIC					0
M	10	47	31*	184.4	1.00	-E	14.0	61	58.6	SA			+	+	7
	12	42	22	130.5	1.00	-E	13.0	65	46.1	MV-AP	+			+	0
g	14	46	28	310.1	0.99	-E	20.0	75	74.6	MV-AP-RV	+	+			2
r	15	52	33	211.8	0.66	-E	15.5	69	63.5	SA-MV		+	+		0
o	16	55	35	131.9	0.76	-E	14.8	70	44.0	S-MV					(
u	17	53	33	185.5	1.00	-E	14.8	57	57.2	SYMMETRIC		+			0
p	18	41	37*	155.6	0.79	-E	15.0	56	56.8	SA-MV-AP		+			0
	19	38	21	139.0	0.78	-E	13.0	76	39.0	SYMMETRIC					0
	20	40	37	186.5	0.62	-E	17.0	64	51.2	SYMMETRIC		+		+	10
	21	45	28*	186.5	0.79	+E	15.5	78	51.5	SYMMETRIC		+			0
	22	39	36	161.7	0.95	-E	13.7	77	54.5	SYMMETRIC	+				0
	23	55	42	150.5	0.71	-	13.0	70	65.0	SYMMETRIC					0
	8	50	43	138.0	0.75	+	11.2	46	50.5	SYMMETRIC					0
	11	39	35*	99.5	2.00	-	9.0	46	58.7	SYMMETRIC					0
	13	30	24	141.3	0.78	-	13.7	71	56.1	SYMMETRIC	+				0

ITW age: Age of subjet when first EKG with isoelectric T waves was performed. LV: Left ventricular. EXER. TEST: Bruce treadmill test (electrically positive (+) or negative (-), E: T waves turned positives during exercise. R: T-waves turned positives into recovery phase). Distrib LV mass: LV mass distribution. SA: septal anterior. MV: mid ventricular. AP: apical. RV: right ventricle. NEG T III-aVF: cases with negative T-waves in III and aVF ECG leads. SAM: Mitral valve systolic anterior motion. ASC: Partial aortic valve leaflets midd-systolic clossure. SHQ: septal hypokinesia. VPC 24h: number of ventricular premature complexes in 24 hours Holter monitoring. (See Table II for other abbreviations).

scintigraphy was negative in thees two cases). Finally case number 13 has a high probabi..ty of HCM: It have SWT of 13.6 mm, decreased compliance, and high LV mass, but not enough to reach the established l.mit, so we coud not include it as HCM.

LV hipertrophy was symetric in 11 out of the 20 cases, envolving anterior portion of LV septum in 6 cases. We did not find any apical HCM type.

Eco-Doppler meassurements of HCM and control groups, and comparative statistical analysis are showed in table IV. Left atrium was significatly larger in the HCM group. We found it slightly dilated in 6 out the 20 cases, but never above 40 mm. LV out-flow obstruction could not be found in any case.

All subjects were abble to conclude, at least, the 2nd minute in the 4th step of the Bruce protocol. ST was clinicaly negative in

TABLE IV: ECO-DOPPLER MEASUREMENTS IN CONTROL GROUP AND IN SUBJECTS WITH HYPERTROPHIC CARDIOMYOPATHY

	Control (n=15)		HCM subjects (n=20)		
	$\bar{x}$	±SD	$\bar{x}$	±SD	p
Age	41.47	7.32	44.20	6.91	NS
BSA m²	1.89	0.13	1.88	0.08	NS
Aorta	29.30	3.58	31.28	3.37	NS
LA	31.13	3.16	34.31	3.46	<0.01
LVSWT	9.36	0.87	14.53	1.68	<0.001
LVPWT	8.68	0.79	11.97	1.84	<0.001
LVIDd	49.58	3.43	46.98	3.89	NS
EF %	64.40	6.83	69.65	7.87	<0.05
LVEDV/m²	62.20	8.04	54.96	9.26	<0.05
LV mass/m²	103.62	12.86	175.42	40.40	<0.001
Peak E	80.55	16.71	60.15	10.94	<0.001
Peak A	46.31	11.68	67.95	18.55	<0.001
E/A ratio	1.74	0.32	0.94	0.33	<0.001
Peak Ao	106.60	13.65	106.25	15.83	NS

(See Tables I and II for abbreviations).

BSA: Body surface Area. LVEDV: Left ventricular end-diastolic volume. EF: Ejection Fraction. LA: Left atriun. LV: Left ventricle. LVIDd: Left ventricular Internal diastolic Diameter (mm). p: stadistical signification level. Peak A: Peak late diastolic filling velocity (cm/seg). Peak Ao: Peak aortic flow velocity (cm/seg). Peak E: Peak early diastolic filling velocity (cm/seg).

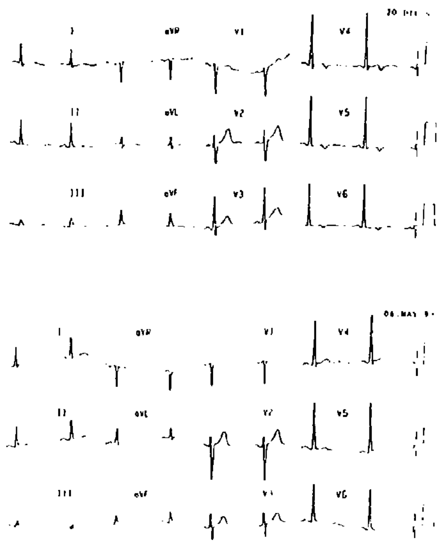


Figure 3: Patient nº 21, 45 years old. All his previous EKG records were normal. EKG showed on top belongs to a pilot who started three months earlier a physical training program including isometrics exercises. The bottom figure was performed 6 montns after quitting exercice program.

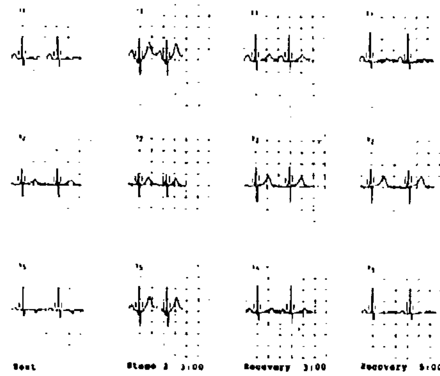


Figure 4: EKG changes during Bruce test. T-wave become positive during exercise, returning to basal size at recovery time.

all cases, and electrically positive in only one case (number 21) out of twenty. In this case, isotopic study (SPECT, Tc-99) was normal, and assesed as false positive.

Figure number 4 shows T-wave changes in V5 lead, troughout treadmill test in a HCM group's patient. T-wave turned to normal during exercise phase of the Bruce protocol, returning to basal shape in the recovery period. We found this pattern in 16 out of the 20 cases with HCM (figure 5). In the control group the previous positive T wave, increased later, during recovery time.

During ET, systolic blood pressure above 200 mm Hg, or diastolic blood pressure above 90 mm Hg was not recorded. Cardiac arrytmias were not present.

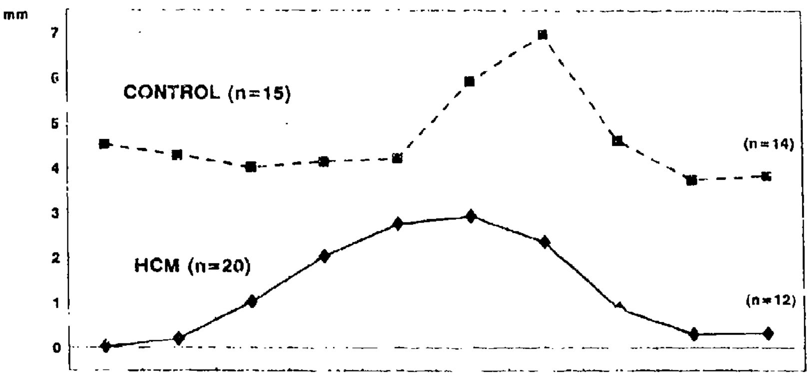
Holter recorders did not show pathological findings. Only many low density monomorphic PVCs were recorders in 6 cases (table III). PVC were recorded in 5 control group cases. We did not find statistical diferences between both groups.

DISCUSSION:

Our findings sugest that a significant flying population (87%) of asimptomatic aircrew members with EKG pattern showing isoelectric T-wave in all leads but not in V2-V3, with or without negative T waves in III and avF leads, are carriers of mild or moderate HCMs.

T-wave's abnormalities are very common in well trained sportmen (9). It was demostrated by Talio-201 scintigrafic studies (10) that they do not arise from perfusional disorders, but literature showed that subjects with that ECG's abnormalities have a higher mortality rate due to sudden death and necropsy showed HCM in many of these cases (11).

Nowdays, it is admited that a IVSWT of 13 mm or more, without arterial hypertension, aortic stenosis or another justificative reason, is compatible with the diagnosis of HCM. Very often, sportsmen' LVH may lead to a difficult assess, but it had been demostrated



	REST	S1	S2	S3	S4	R1	R3	R5	R7	R10
CONTROL ■	4.533	4,3	4,033	4,167	4,233	5,933	6,967	4,633	3,767	3,857
SD	1.807	1,386	1,653	1,566	1.678	2,313	1,941	1,529	1.163	1,2
p<						0,1	0,005			
HCM ◆	0.025	0,2	1,025	2,05	2,775	2,95	2,37	0,87	0,3	0,333
SD	0,734	0,965	1,428	1,575	1,658	1,45	1,919	1,432	0.817	0,536
p<			0,01	0,001	0,001	0,001	0,001	0.05		

Figure 5: T wave high, at the end of each Bruce test stages, in both, control and HCM subjects groups. Statistical probabilities (p) was calculates in each stages, compared with resting values.

(12) that IVSWT more than 13 mm only appears in very specific sports like rowers or canoers and, very rarely in bike riders. In all of those cases, LV appear dilated, and LV compliance is normal or increassed (12-14).

Though with age LV compliance decrease, a mitral flow E/A ratio below 1 is exceptional to found it in normal people before age of 55-60 (15). That decreassed compliance could be responsible of the light left atrial enlargement we found in our patiens with HCM.

Meassurement of LV mass, may be more accurate taked by two-dimensional images in cases whith asymmetrical LV hypertrophy. According with some authors (16, 17) in our experience to trace accurately, the endocardical edge, very often, has a lot of limitations On the other hand, M-mode recorders under two-dimensional control gave us accuracy reproductibles meassurements. Perhaps, in some cases, we underestimate LV mass, but never overestimate it. Never septal or posterior wall were thicker in the basal segments than in the other segments. In addition, when anterior portion of septal wall was larger than the posterior one, we considered the arithmetical mean between both values.

Although mitral systolic anterior mouvement (SAM) and mid-sistolic aortic valvular clossing are more common in obstructive HCM, it is frequent to find it in the non-obstructive HCM (18). These findings are show in table III.

We did not find any obtructive form of HCM but, we think that it does not mean that it is not possible to find it in subjets with ECGs patterns as we described. We should take into account that we had been studing a healty population belonging to a risk job, who had been previously selected after a carefully medical exam, and following a periodical exam.

We should pay atention to T-wave changes during ET in HCM group (figure 5). T-wave start to be positive at the end of the Bruce second steep. There is a steping increasing until the fourth one, begining to decrease from the first minute of the recovery time. Those findins appeared in 16 ot of the 20 cases with HCM (80%), and none in the control group, so we consider they are very specific of HCM. The T-wave behaviour may be related with one case described by Lheman et al (19), one HCM in a 52 years old man, in wich giants negative T-waves turned positives during ET.

It has been demonstrated that patiens with HCM, very often, developpe cardiac arrythmias, and Holter monitoring demonstrated ventricular arrhytmias in 45% of these patients (20), described as the most common form of sudden death (21,23). However, in 90% of cases, sudden death in HCM patients, it happens before age of 25. Mortality appears to be independent of obstructive or non obstructive myocardiopathy. It is rather common in septal assymetric cases with very abnormal EKG patterns, including high potentials, abnormalities in ST-T wave and larges and profounds Q waves, having very frequently, familiary history of sudden death (24). Mortality is 3 times more frequent when EKG recorder shows the above described abnormalities (20).

In our cases, Holter monitoring recorders did not show significatives arrythmias. This findings are rather different from those described in the literature (20, 21, 23). Holter monitoring results are similar in the MCH group to those in the control group, but less than data presented by Kostis et al (25). They found VPCc in 46% of Holter recorders in normal people, having 20% more than 10 and 5% more than 100 across 24 hours.

We think than HCM is a cardiopathy with an

incidence higher than what it is currently published. In the Reikiavich study (20), HCM was found in 0.8% of male people with normal EKG, and in 1.1 % of those with abnormal EKG, with a global prevalence of 1.1%. We have noted MCH in 0.75 % of healtly male adult people, but incidence should be higher if we include cases non clinically manifested before to be adult, obstructive HCMs or other with abnormal EKG patterns, excluded for flying duty since the begining. We have not taken into account cases with HCM and normal EKG. The may be not few because we could see to change EKG from normal pattern to the described isoelectric T-wave pattern in 18 ou of our 23 cases. This ECG pattern change was showed between ages of 21 and 43, because of that we should expect to find new cases in the following years. However, these cases possibly will be rare enough in the time being, once ECHO-Doppler was performed in the initial evaluation of pilots, before active flying duty.

Main question arise from the prognosis and further management of those flyers. In our experience follow up do.s not shown any significant abnormality and we could assume the prognosis as very benign, acctually more than other series described in the literature. In the benign cases described for Spirito et al (26), across 4 a following of 4 years, 25 % of his patients had symptoms. In our cases the following is much longer (13.0±6.6 years, in some cases 20 years). During this period no one had symptoms that we could attribute to his HCM. They did not show ventricular arrhytmias in holter monitoring. Decreassing of LV compliance are more relevant than the findings of Spirito et al (26). Niemaber et al (27) found those patients more prone to sincope in HCM, when LVEDV was less than 60 ml/m². Our cases did not have sincope although many cases had LVEDVs smallers than 50 ml/m².

Although the benign course of those HCM, we suggest to avoiding heavy exercise, specialy isometric exercise. Mild aerobic should not be a formal contraindication. Lhemann (19) describe a patient who from the almost normality developed a severe HCM, after practising heavy exercise. We observed, that after limiting the exercise, ECG pattern improve clearly, as well as improve E/A ratio in Doppler mitral flow, that means and improvement of the LV compliance. Doppler-echocardiography are recomemnded for measuring LV compliance, as well as EKG and Holter recorder, in the following of these pilots.

Arterial blood pressure must be keep into normal limits in this subjects, since it was demonstrated (28) that hypertension is able to act over HCM leading to more serious formes with giant negative T-waves in EKG.

We think these are HCM clinical forms, at that time benigm forms, but they would lead to more dangerous HCM patterns, with worse prognosis. Only one of our cases was a high perfomances aircraft pilot, although, his good flying tolerance demonstrated by Holter monitoring and during human centrifuge training, we considered prudent to restring his flying dutyes to conventional aircrafts.

We think that isoelectrics T-wave like above described are strongly suspicious of HCH, specially when T waves turned normals in ET. When we found this EKG pattern, we must perform, in a first time, a ECHO-Doppler study, and not focus our attention looking for coronary disease.

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EPREUVE EN CENTRIFUGEUSE DANS LE CADRE DE L'APTITUDE MEDICALE DES PILOTES DE CHASSE FRANCAIS

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RESUME

L'aptitude au pilotage peut être remise en question lors de la survenue de processus pathologiques dont l'étiologie n'est pas toujours connue. Dans l'Armée de l'Air Française, après un épisode pathologique important, les pilotes sont soumis a une expertise médicale qui conditionne la reprise des vols. Lorsqu'il est nécessaire de s'assurer qu'il n'existe aucun risque lié aux accélérations, les pilotes sont soumis, au Laboratoire de Médecine Aérospatiale, à une épreuve standardisée en centrifugeuse.

De 1983 a 1993, 112 épreuves en centrifugeuse ont été pratiquées. Les affections ayant motivé une épreuve en centrifugeuse sont très largement dominées par des malaises et pertes de connaissance et des troubles cardio-vasculaires qui sont essentiellement des anomalies électrocardiographiques transitoires. Dans certains cas, les troubles initiaux ont été reproduits et analysés. L'épreuve en centrifugeuse a souvent permis d'éviter que ne soit prononcée par excès une décision d'inaptitude, lourde de conséquences pour les pilotes, sur le plan psychologique, et pour l'Armée de l'Air, sur le plan de l'investissement de la formation opérationnelle.

1. INTRODUCTION

Les pilotes de combat peuvent présenter, au cours de leur carrière ou en début de formation, des affections aigues ou chroniques. Il est alors nécessaire de s'assurer que ces affections ou leurs répercussions ne mettent pas en jeu la sécurité des vols et, par conséquent, l'aptitude au pilotage. Dans la majorité des cas, les pilotes Français présentant ce type de problème font l'objet d'un bilan pratiqué dans un Centre d'Expertise Médicale du Personnel Navigant et éventuellement d'un bilan complémentaire dans le Service de Médecine Aéronautique de l'Hôpital d'Instruction des Armées (HIA) Dominique Larrey, à Versailles. Dans le cadre de ce bilan complémentaire, plusieurs investigations sont menées.

Pour s'assurer que les accélérations $+G_Z$ ne soient à l'origine d'une décompensation ou d'une aggravation de la pathologie initiale, une épreuve en centrifugeuse est alors pratiquée. Elle a pour but de rechercher un lien de cause à effet entre le facteur de charge et la pathologie présentée par le sujet, ou bien d'évaluer le retentissement exact de l'affection, lors des accélérations $+G_Z$. L'épreuve en centrifugeuse est réalisée dans sa forme actuelle depuis 1983 au Laboratoire de Médecine Aérospatiale, au Centre d'Essais en Vol, à Brétigny-sur-Orge (Clère et coll., 1989).

Le but de ce travail est de dresser le bilan des 112 expertises effectuées au cours des 11 dernières années, de 1983 à 1993, chez 107 pilotes, 5 d'entre eux ayant été soumis à l'épreuve en centrifugeuse à deux reprises.

2. MATERIEL ET METHODES

2.1. Matériel

L'exposition aux accélérations $+G_Z$ est réalisée grâce à la centrifugeuse humaine du Laboratoire de Médecine Aérospatiale. Dotée d'un bras de 6 mètres, cette centrifugeuse peut délivrer des mises en accélération maximales voisines de 1 G/s.

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Le pilote fait l'objet d'une surveillance visuelle grâce à un système vidéo permettant d'enregistrer l'intégralité de l'épreuve et un circuit phonique permet de communiquer en permanence avec lui.

L'enregistrement des paramètres physiologiques comporte.

- le recueil de l'activité électrocardiographique (ECG) sur 3 dérivations standard,
- la mesure de la pression artérielle, par une méthode acoustique classique utilisant un brassard pneumatique télécommandé,
- la mesure du champ visuel sur un méridien horizontal situé devant les yeux du sujet. Cette mesure est effectuée grâce à une rampe semi-circulaire de 70 centimètres de rayon, la tête du sujet étant positionnée en son centre. Elle comporte dix huit voyants lumineux de couleur blanche, séparés entre eux par 10 degrés d'arc, et un voyant lumineux central de couleur rouge. Le sujet doit fixer le voyant rouge et détecter l'allumage d'un des voyants latéraux les plus périphériques, à droite ou à gauche. Il doit signaler sa perception en pressant un bouton poussoir situé sur un mini manche tenu en main droite. L'absence de détection entraîne, environ trois secondes plus tard, l'allumage d'une lampe située plus en avant, de 10 degrés. Cette nouvelle situation correspond alors à une perte totale de champ visuel de 20 degrés sur le méridien horizontal.

2.2. Méthode

2.2.1. Protocole de l'épreuve

L'épreuve en centrifugeuse comporte deux sessions espacées de 30 minutes.

La première session comporte une succession de plateaux incrémentés d'accélération de 4, 5, 6 et 7 $+G_Z$, délivrés selon une mise en accélération de type ROR (Rapid Onset Rate) à 1 G/s. Chaque plateau est maintenu pendant 20 secondes. Au cours de cette première session, le sujet ne bénéficie pas d'équipement de protection anti-G; par contre, il peut effectuer des manoeuvres musculo-respiratoires à partir du second plateau d'accélération stabilisée, à 5 $+G_Z$, s'il en ressent le besoin, pour améliorer sa tolérance au facteur de charge.

La deuxième session comporte une exposition à un plateau d'accélération unique à 7 $+G_Z$ (jolt: 1 G/s), d'une durée de 20 secondes. Le sujet est alors protégé par un pantalon anti-G (ARZ 820), pressurisé selon une loi Française classique de 70 hPa/G (environ 1 psi/G), de 2 à 9 $+G_Z$. Il peut également pratiquer des manoeuvres anti-G volontaires. Ce deuxième lancement est conforme au STANAG OTAN 3827.

2.2.2. Interprétation des résultats

Les données recueillies tout au long de l'épreuve sont analysées pour la période de contrôle précédant le lancement, chaque niveau de plateau d'accélération, la phase de décélération, puis 30 secondes et 3 minutes après l'arrêt de la centrifugeuse. Les principaux paramètres analysés, au cours de chacune de ces périodes, sont la fréquence cardiaque, obtenue à partir de l'ECG, les pressions artérielles systolique et diastolique et l'amplitude du champ visuel sur le méridien horizontal. De plus, l'ECG fait l'objet d'une interprétation simplifiée, compte-tenu du faible nombre de dérivations enregistrées.

Les anomalies cliniques décelées par le médecin ou le sujet lui-même, en cours d'épreuve ou à l'issue, sont également relevées.

Dans certains cas, lorsque l'expertise porte sur des anomalies de l'ECG, le sujet est porteur d'un Holter ECG au cours de l'épreuve en centrifugeuse.

3. RESULTATS

3.1. Données épidémiologiques générales

La quasi totalité des 112 épreuves a été demandée par le Service de Médecine Aéronautique de l'HIA Dominique Larrey, les autres étant pratiquées à la demande du Centre Principal d'Expertise du Personnel Navigant.

Les catégories de pilotes soumis à l'épreuve en centrifugeuse sont celles qui sont susceptibles d'être exposées à des accélérations $+G_Z$ en vol. Il s'agit de:

- pilotes de chasse, ayant effectué en moyenne 2 000 heures de vol: 51%,
- élèves pilotes, ayant accompli en moyenne 135 heures de vol: 38%,
- moniteurs, totalisant plus de 3 000 heures de vol: 9%,
- pilotes d'essais: 2%.

Les pathologies ayant motivé l'épreuve en centrifugeuse sont réparties en:
- malaises et des pertes de connaissance (PC), survenues en vol ou en dehors du vol: 41%,
- pathologies cardio-vasculaires: 30%,
- affections thoraco-pulmonaires: 8%,
- affections rachidiennes: 8%,
- affections diverses: 13%.

A l'issue de l'épreuve en centrifugeuse, en fonction des résultats obtenus, mais également, en fonction d'autres examens complémentaires, le spécialiste du Service de Médecine Aéronautique, a proposé au Centre Principal d'Expertise du Personnel Navigant une décision concernant l'aptitude au pilotage. Cette proposition, connue pour 103 des 112 expertises, chez 98 pilotes, était en faveur des décisions suivantes:
- aptitude sans restriction: 30%,
- aptitude temporaire de 3 à 12 mois, avec nouveau bilan hospitalier à l'issue: 25%,
- aptitude par dérogation aux normes médicales: 13%,
- reclassement dans une catégorie exempte d'expositions aux accélérations de haut niveau: 17%,
- inaptitude temporaire: 2%,
- inaptitude définitive: 13%.

La proposition concernant la décision d'aptitude, a été étudiée en fonction de la catégorie des pilotes expertisés. La répartition des avis sur l'aptitude, en fonction de la spécialité aéronautique, sur l'ensemble des cas pour lesquels ils sont connus, est la suivante:
- aptitude sans restriction: 12 élèves pilotes, 15 pilotes de chasse et 3 moniteurs,
- aptitude temporaire: 6 élèves, 18 pilotes de combat et 2 moniteurs,
- aptitude par dérogation aux normes médicales: 1 élève pilote, 10 pilotes de chasse et 2 moniteurs,
- reclassement: 11 élèves pilotes et 7 pilotes de chasse,
- inaptitude définitive: 12 élèves pilotes et 1 pilote de chasse.

3.2. Données recueillies en cours d'épreuve en centrifugeuse par types de pathologie

3.2.1. Malaises et pertes de connaissance (PC):

Les 43 cas de malaises et PC, chez 41 sujets, se répartissent à parts égales. Les malaises et PC ont été identifiés en vol dans 79% des cas et en dehors du vol dans 21% des cas. Les 79% de troubles observés en vol sont représenté par la somme de 43% de malaises et 36% de PC. Les 21% de troubles observés en dehors du vol sont représenté par la somme de 7% de malaises et 14% de PC.

La répartition par spécialités des pilotes soumis à l'épreuve en centrifugeuse pour malaises ou pertes de connaissance est de 63% pour les élèves pilotes, de 33% pour les pilotes de chasse et de 4% pour les moniteurs et autres catégories.

Les malaises en vol ont affecté en moyenne une proportion de 4 élèves pour 6 pilotes confirmés tandis que les PC en vol ont affecté en moyenne une proportion de 8 élèves pour 2 pilotes de combat.

Dans 53% des expertises en rapport avec ce type de symptomatologie, l'épreuve en centrifugeuse n'a pas mis en évidence d'anomalie particulière. En revanche, elle a permis de reproduire la symptomatologie dans 23% des cas. Pour les 2-% restant, d'autres anomalies ont été observées; il s'agit, le plus souvent, de troubles du rythme cardiaque, ou de troubles apparentés à la symptomatologie ayant motivé l'expertise, mais leur importance est moindre (par exemple des troubles du champ visuel chez un sujet expertisé pour une perte de connaissance), ou plus grande (par exemple une perte de connaissance chez un sujet expertisé pour malaise en vol).

Sur le plan de l'aptitude, au terme de l'expertise des malaises et pertes de connaissance, le spécialiste de Médecine Aéronautique s'est prononcé en faveur des décisions suivantes:
- aptitude sans restriction dans 10 cas sur 43 (23%), chez 7 élèves pilotes, 2 pilotes de chasse et 1 pilote d'essais. Dans tous les cas, l'épreuve en centrifugeuse a été strictement normale.
- aptitude temporaire avec nouveau bilan hospitalier à l'issue dans 8 cas sur 43 (19%), chez 2 élèves pilotes et 6 pilotes de chasse. La symptomatologie n'a été reproduite en centrifugeuse que dans 1 cas, et d'autres anomalies ont été observées dans 2 cas.
- reclassement dans des catégories autres que l'aviation de chasse dans 11 cas sur 43 (26%),

chez 7 élèves pilotes et 4 pilotes de combat en début de carrière, ayant à leur actif 400 à 1100 heures de vol. La symptomatologie n'a été reproduite que dans 2 cas au cours de l'épreuve en centrifugeuse; une symptomatologie différente a été retrouvée dans 3 cas.

- inaptitude temporaire chez 1 pilote de chasse qui n'a pas présenté d'anomalie particulière au cours de l'épreuve en centrifugeuse.
- inaptitude définitive dans 10 cas sur 43 (23%). Celle-ci a été prononcée chez 9 élèves pilotes et 1 pilote de combat ayant 1600 heures de vol à son actif. La symptomatologie a été reproduite en centrifugeuse dans 6 cas; les 4 cas restant ont présenté d'autres troubles (voile noir associé à des troubles du rythme cardiaque dans 2 cas, troubles du rythme cardiaque à type d'extrasystolie ventriculaire dans 1 cas et PC dans 1 cas).

Dans 3 cas sur 43 (7%), la décision d'aptitude n'est pas connue.

3.2.2. Pathologie cardio-vasculaire

Une pathologie cardio-vasculaire a fait l'objet d'une épreuve en centrifugeuse dans 36 cas, chez 34 pilotes. Ces derniers étaient des pilotes de chasse dans 71% des cas, des élèves pilotes dans 23% des cas et des moniteurs dans 6% des cas.

Les affections en cause sont des anomalies de l'ECG dans 26 cas (72%), représentées par des troubles du rythme cardiaque et des troubles de la conduction (extrasystolie auriculaire et/ou ventriculaire, bloc auriculo-ventriculaire du 1er ou du 2nd degré, bloc de branche droite ou gauche complet ou incomplet). Dans 6 cas (17%), les sujets présentent des valvulopathies modérées (insuffisances mitrale et/ou tricuspidienne, prolapsus mitral, insuffisance aortique). Dans 4 cas (11%), une hypertension artérielle (HTA) est en cause (3 HTA sous traitement médicamenteux et 1 HTA d'effort).

Au cours de l'épreuve en centrifugeuse, la symptomatologie a été reproduite dans 16 cas (44%); d'autres troubles ont été observés dans 8 cas (22%) dont 3 cas avec PC.

Sur le plan de l'aptitude, au terme de l'expertise des pathologies cardio-vasculaires, le spécialiste de Médecine Aéronautique s'est prononcé en faveur des décisions suivantes (33 cas connus sur 36):

- aptitude sans restriction dans 8 cas (22%), chez 1 élève, 6 pilotes de chasse et 1 moniteur, pour troubles du rythme dans 3 cas, troubles de la conduction dans 4 cas et HTA traitée médicalement dans 1 cas,
- aptitude temporaire dans 11 cas (31%), chez 1 élève, 7 pilotes de chasse et 3 moniteurs, pour troubles du rythme dans 5 cas, troubles de la conduction dans 2 cas, valvulopathies associées à des troubles du rythme dans 2 cas et HTA dans 2 cas (dont 1 traitée médicalement),
- reclassement dans des catégories autres que l'aviation de chasse dans 5 cas (14%), chez 2 élèves pilotes et 3 pilotes de chasse, pour valvulopathie dans 2 cas et troubles du rythme dans 3 cas,
- aptitude par dérogation aux normes médicales dans 7 cas (19%), chez 1 élève, 5 pilotes de chasse et 1 moniteur,
- inaptitude temporaire dans 1 cas, chez un pilote de chasse présentant une extrasystolie ventriculaire reproductible à l'épreuve en centrifugeuse. Trois mois plus tard, à l'issue d'une deuxième épreuve en centrifugeuse, un avis favorable pour une aptitude temporaire a été émis, les troubles reproduits ayant une apparence bénigne,
- inaptitude définitive dans 1 cas, chez un élève pilote ayant présenté un trouble du rythme à type de dysfonction sinusale, reproduit à l'épreuve en centrifugeuse au cours de laquelle une extrasystolie ventriculaire a également été mise en évidence.

3.2.3. Pathologie thoraco-pulmonaire:

Les affections thoraco-pulmonaires pour lesquelles une indication d'épreuve en centrifugeuse a été posée, sont au nombre de 9 (8%). Un cas présente une sarcoïdose médiastino-thoracique, mais dans la majorité des cas il s'agit d'affections chirurgicales consolidées (8 cas), constituées par 1 cas de tumeur pleurale bénigne opérée et 7 cas de pneumothorax ayant subi une symphyse pleurale plusieurs mois auparavant, souvent accompagnée d'une résection de dystrophie bulleuse pulmonaire. Deux expertises ont été effectuées chez le même sujet qui a présenté, à

4 ans d'intervalle, un pneumothorax spontané de chaque coté. Dans l'un des cas, le pneumothorax est survenu pendant le vol, au cours de la pratique de voltige.

Les pneumothorax opérés soumis à l'épreuve en centrifugeuse ont affecté 3 élèves pilotes, 2 pilotes de chasse (à 2 reprises pour l'un d'entre eux) et 1 moniteur.

L'épreuve en centrifugeuse n'a jamais mis en évidence de symptomatologie en rapport avec l'affection initiale. Dans 3 cas, des anomalies de l'ECG, à type d'extrasystoles ventriculaires isolées, ont été retrouvées, mais leur apparence était bénigne.

La proposition d'aptitude du spécialiste, connue dans 8 cas, est:
- aptitude sans restriction: 4 cas (1 élève et 3 pilotes de chasse),
- aptitude temporaire: 2 cas (1 élève et 1 pilote de chasse),
- aptitude par dérogation aux normes médicales: 2 cas (1 pilote de chasse et 1 moniteur).

3.2.4. Pathologie rachidienne:

Les affections rachidiennes pour lesquelles une épreuve en centrifugeuse a été indiquée, sont constituées par 1 cas de lombosciatique en cours de rémission, sous traitement médicamenteux, et 7 cas de hernie discale ayant subi une cure chirurgicale plusieurs mois auparavant. Dans l'un des cas, chez un pilote de chasse, une hernie discale affectait le rachis cervical.

Au cours et au décours de l'épreuve en centrifugeuse, aucune symptomatologie rachidienne n'a été observée.

A l'issue de l'expertise, les propositions d'aptitude émises par le spécialiste étaient:
- aptitude sans restriction: 5 cas (4 pilotes de chasse et 1 moniteur),
- aptitude par dérogation aux normes médicales: 3 cas (tous pilotes de chasse).

3.2.5. Pathologies diverses:

Dans 14 cas, diverses pathologies ont fait l'objet d'une indication de l'épreuve en centrifugeuse. Les pathologies les plus fréquentes sont les affections chirurgicales abdominales traitées. Parfois, une pathologie atypique a motivé l'indication de l'épreuve en centrifugeuse, pour écarter la possibilité de récurrence des troubles sous accélération: manifestations électro-encéphalographiques de type pointes-ondes, paralysie du nerf moteur oculaire commun en vol sous accélérations, hémorragies du corps vitré. Dans un cas, la bonne tenue sous accélérations d'un implant cristallinien a été vérifiée.

De manière générale, ces diverses pathologies n'ont pas été reproduites ou aggravées. Dans 4 cas, des extrasystoles ventriculaires isolées, d'apparence bénigne, ont été mises en évidence au cours des lancements.

A l'issue de l'expertise, les propositions d'aptitude émises par le spécialiste étaient:
- aptitude sans restriction: 4 cas,
- aptitude temporaire: 5 cas,
- reclassement: 1 cas,
- inaptitude définitive: 1 cas.

4. DISCUSSION

4.1. Indications

L'analyse épidémiologique des cas pour lesquels l'indication d'une épreuve en centrifugeuse a été posée recouvrent un éventail de pathologies relativement restreint. En effet, dans un nombre important d'expertises, le diagnostic étiologique et le pronostic des affections en cause, face à l'exposition aux accélérations, sont relativement biens connus et par conséquent, la décision d'aptitude peut être prise sans ambiguïté. Il n'en n'est pas de même au cours de certaines affections transitoires ou mal définies, telles que les malaises en vol ou en dehors du vol, et des anomalies dont le pronostic, sous accélération, est incertain, en particulier pour certaines anomalies transitoires de l'ECG ou pour des affections chirurgicales traitées pour lesquelles l'exposition aux accélérations constitue un risque potentiel. Le spécialiste chargé d'émettre un avis sur l'aptitude au vol de sujets présentant de telles symptomatologies et susceptibles d'être soumis à des contraintes physiologiques importantes telles que les accélérations, redoute le risque de survenue d'une incapacitation soudaine en vol, en particulier sur un avion monoplace. Par conséquent, l'exposition aux accélérations en centrifugeuse peut lui apporter des arguments précieux pour

formuler un avis sur l'aptitude. De manière générale, l'épreuve en centrifugeuse, qui n'est pas un examen anodin, n'est jamais prescrite si les autres examens para cliniques subis par le pilote permettent d'émettre un avis d'inaptitude (Seigneuric, 1993).

4.2. Difficultés méthodologiques

L'épreuve en centrifugeuse permet le recueil de paramètres physiologiques objectifs donnant des indications sur l'adaptation hémodynamique et la tolérance des sujets au facteur de charge. Des difficultés méthodologiques sont souvent rencontrées. Certaines de ces difficultés sont liées au caractère dynamique de l'épreuve. Par exemple, l'enregistrement électrocardiographique peut être fortement parasité par le recueil simultané d'un signal électromyographique généré par la pratique de manoeuvres anti-G volontaires, malgré une disposition particulière des électrodes. Dans ce cas, l'interprétation de l'ECG peut être extrêmement difficile. De même, la contraction volontaire des membres supérieurs pose souvent des problèmes de mesure de la pression artérielle au brassard. D'autres difficultés méthodologiques sont liées au caractère interactif des tests pratiqués. Ainsi, la mesure du champ visuel sur l'axe horizontal ne fournit des informations que toutes les 3 à 4 secondes. De plus, elle n'a de valeur que si le test de détection de l'allumage des lampes est bien pratiqué par le sujet. Dans certains cas, l'attention du sujet est focalisée sur les troubles subjectifs qu'il perçoit, si bien que le test de champ visuel est délaissé et la perte de champ visuel mesurée est en fait supérieure à sa valeur réelle. Dans d'autres cas il peut ne pas fixer correctement le voyant rouge central et effectuer des mouvements oculaires; il est alors nécessaire de lui rappeler de fixer son regard. A l'opposé, le sujet peut, a certains moments fournir des réponses indiquant une perte de champ visuel moins importante que la perte de champ visuel réelle. Ces réponses peuvent avoir deux origines: dans certains cas, le sujet minimise volontairement la diminution de sa tolérance par crainte d'une répercussion défavorable sur l'avis d'aptitude qui sera émis; dans d'autres cas, il peut présenter des scotomes positifs dans son champ visuel périphérique, alors que la perte de champ visuel central est avérée, comme le démontre la dérive du regard qui ne peut plus être fixé sur le voyant rouge central. Toutefois, malgré ces nombreuses difficultés méthodologiques, la mesure du champ visuel constitue dans la majorité des cas un bon index de tolérance aux accélérations, à condition d'en connaître les limites.

4.3. Intérêt de l'épreuve en centrifugeuse

Les pathologies pour lesquelles l'épreuve en centrifugeuse est indiquée sont très nettement dominées par les malaises et pertes de connaissance d'une part et par des anomalies de l'ECG qui sont souvent découvertes au cours d'examens systématiques d'autre part. Ces pathologies sont à l'origine de nombreuses expertises effectuées par le Service de médecine Aéronautique. Cependant, peu de cas sont présentés à l'épreuve en centrifugeuse. D'une part, tous les sujets concernés ne sont pas susceptibles d'être exposés aux accélérations et d'autre part, dans un nombre important de cas, la découverte de causes organiques ou psychologiques suffit pour statuer sur l'aptitude au pilotage (Burlaton et Seigneuric, 1992; Burlaton et coll., 1993).

Pour la série présentée dans cette étude, les malaises et pertes de connaissance prédominent chez les élèves pilotes. En vol, les malaises sont plutôt l'apanage des pilotes confirmés alors que les pertes de connaissance sont plutôt le fait des élèves pilotes.

L'intolérance aux accélérations liée à une inadaptation cardio-vasculaire n'est observée que chez un pilote sur quatre ayant présenté préalablement des malaises ou des pertes de connaissance. La quasi totalité de ces pilotes étaient des élèves qui ont fait l'objet d'une inaptitude définitive. En revanche, tous les pilotes déclarés aptes sans restriction (quasi exclusivement des élèves pilotes) n'ont présenté aucun trouble au cours de l'épreuve en centrifugeuse. L'épreuve en centrifugeuse a constitué un test clé dans la prise de décision d'aptitude. Elle a certainement permis à l'expert, dans un nombre important de cas, de maintenir une aptitude sans restriction pour des élèves pilotes en début de carrière, alors que la tendance générale est d'écarter cette catégorie

de sujets, sur des critères qui sont souvent d'ordre économique (Gourbat et Gallé-Tessonneau, 1993).

Parmi les expertises motivées par une pathologie cardio-vasculaire, la proportion d'anomalies électrocardiographiques est très importante (72% des causes cardio-vasculaires). Ces anomalies prédominent nettement chez les pilotes confirmés (77% des cas). On peut penser que les pilotes de chasse sont particulièrement exposés à ce type de pathologie, en raison du caractère très arythmogène des accélérations (Clère et coll., 1985; McKenzie et Gillingham, 1993)

Bien que l'épreuve en centrifugeuse révèle des anomalies dans 2 cas sur 3 (cardio-vasculaires ou autres), celles-ci ne présentent pas de caractères de gravité sous accélérations. Cela explique qu'un seul cas d'inaptitude définitive ait été émis, chez un élève pilote.

En ce qui concerne les expertises pour des causes thoraco-pulmonaires ou rachidiennes, pour lesquelles une épreuve en centrifugeuse a été pratiquée, le type de pathologie rencontré est univoque, constitué quasi intégralement par le pneumothorax et la hernie discale traités chirurgicalement. Pour ces pathologies, il était recherché une récupération quasi complète et l'assurance de l'absence de risque sous accélération. L'épreuve en centrifugeuse constitue une véritable "épreuve de réhabilitation", pratiquée dans des conditions de sécurité absolue (Seigneuric, 1993).

D'une manière générale, l'épreuve en centrifugeuse vise à reproduire une symptomatologie attribuée aux accélérations ou bien à évaluer le risque d'aggravation, sous accélérations, de pathologies asymptomatiques. Toutefois, la centrifugeuse humaine n'est qu'un simulateur pouvant générer des contraintes biodynamiques qui lui sont propres. Il en est ainsi des illusions somatograviques de piqué, parfois ressenties en vol, mais particulièrement importantes au moment de l'arrêt de la centrifugeuse. Ces illusions, perçues de manière extrêmement désagréable par certains sujets, pourraient entraîner des troubles différents de ceux qui sont produit en vol. De plus, au cours de l'épreuve en centrifugeuse, les contraintes ressenties par les pilotes sont différentes de celles auxquelles ils sont habitués. Ainsi, leur motivation est très différente de celle qui est suscitée par le vol réel. Fréquemment les sujets effectuent une manoeuvre volontaire de protection anti-G. L'expérience montre que souvent, malgré les informations qui leur sont données pour pratiquer correctement cette manoeuvre, celle-ci est effectuée de façon telle qu'elle aboutit à la survenue de symptômes d'intolérance avant la fin de l'épreuve. Très souvent, également, les sujets pratiquent une polypnée volontaire, génératrice d'une alcalose rapide, défavorable à la tolérance aux accélérations.

Dans un certain nombre de cas, toutes les conditions ayant favorisé une symptomatologie transitoire peuvent ne pas être réunies au cours de l'épreuve en centrifugeuse (conditions thermiques, psychoaffectives, etc.). Malgré ces difficultés méthodologiques, des anomalies reproduites ou aggravées par l'épreuve en centrifugeuse gardent une valeur importante car elles constituent souvent l'un des multiples éléments permettant à l'expert de statuer sur la décision d'aptitude. En effet, lorsqu'apparaissent des troubles objectifs pouvant entraîner une incapacité à piloter, l'expert se prononce pour une inaptitude définitive, et ceci en toute sécurité, en centrifugeuse, et dans un nombre de cas extrêmement limité.

4.4. Perspectives d'avenir

Les avions de combat qui seront mis en service dans un futur proche pourront délivrer des accélérations brutales, intenses et soutenues. Il est probable que pour l'avenir, il sera nécessaire d'adapter les profils d'accélération, au cours du test en centrifugeuse, à la spécialité du pilote. Le pilote d'un avion de combat devant soutenir $9 +G_Z$ devrait alors être soumis à un test en centrifugeuse couvrant le domaine d'accélération de l'avion. En ce qui concerne l'élève, pilotant le plus souvent un avion dont les performances sont moindres, il serait a priori préférable de le soumettre à des profils d'accélération moins élevés, étant donné que son expérience du vol et du facteur de charge ne lui a pas encore permis d'acquérir une

maîtrise correcte des manoeuvres anti-G volontaires. D'un autre côté, ces élèves seront ultérieurement des pilotes d'avions de combat performants et il conviendrait de s'assurer de leur capacité à tolérer des accélérations élevées. Mais dans cette éventualité un entraînement spécifique à ce type d'accélérations serait nécessaire pour évaluer leur tolérance.

Le spécialiste de Médecine Aéronautique sera certainement amené à faire évoluer les expertises vers de nouvelles stratégies pouvant nécessiter le recueil de données physiologiques supplémentaires, telles que la mesure continue de la pression artérielle ou du débit sanguin cérébral sous facteur de charge (Ossard et coll., 1994). Dans la perspective de la réalisation d'une nouvelle centrifugeuse de recherche à hautes performances, actuellement en cours d'étude, au Laboratoire de Médecine Aérospatiale, le protocole de l'épreuve en centrifugeuse devra certainement être adapté au cours d'une concertation entre les cliniciens et les physiologistes pour réaliser, dans des conditions de sécurité absolue, une épreuve de contrainte bien adaptée aux profils d'accélération auxquels seront soumis les futurs pilotes de combat.

5. CONCLUSIONS

De 1983 à 1993, 112 épreuves en centrifugeuse ont été réalisées au Laboratoire de Médecine Aérospatiale dans le cadre d'expertises médicales de pilotes ou futurs pilotes de chasse. La pathologie en cause est très nettement dominée par des malaises et pertes de connaissance, souvent survenus en vol, et par des anomalies transitoires de l'ECG. Dans certains cas, les troubles initiaux ont été reproduits et analysés. L'épreuve en centrifugeuse a fourni à l'expert des données médico-physiologiques précieuses, pour se prononcer sur la décision d'aptitude, dans des cas où la sécurité des vols pouvait être engagée. Elle a permis dans un nombre important des cas d'éviter que ne soit prononcée par excès une décision d'inaptitude, lourde de conséquences pour les pilotes, sur le plan psychologique, et pour l'Armée de l'Air, sur le plan financier.

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IS THE PILOT FIT FOR FLYING AFTER AN ACCIDENT?

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It has been recommended that a pilot should fly as soon as possible after an aviation accident or incident, provided he is medically fit. This tradition has been successful in many cases and has therefore been accepted as the right thing to do in the flying society. New knowledge about post traumatic reactions related to accidents has led to new procedures in the Royal Norwegian Air Force in the wake of a crash. Since an accident necessarily affects many persons, much like rings in the water after throwing a pebble, the new post accident debriefing procedures cover the involved parts after a survivable accident in addition to the rest of the squadron. A considerable problem with post traumatic emotional reactions are that they are not usually detected right after the accident, but are elements in a process rather than immediate results of the acute event

Most signs and symptoms of emotional failure in aviators are not easily detected, but may appear subtly in performance, safety, satisfaction, and retention problems. On the other side is the emotional failure process insidious and may in its uttermost cosequence lead to sudden incapacitation. There are many conditions which cause sudden incapasitation in aerospace medicine, but they are mainly somatic and easy to identify. The emotional failure of aviators, however, tends to grow over a long period of time in small increments which are difficult to recognize. Another part of the failure to identify these syndromes has to do with the stigma associated with emotional problems. This stigma is a part of the aviation culture which promulgates the idea that loss of self control is cause for personal humiliation and shame. When faced with emotionally ladened issues pilots often try to ignore their emotional reactions and when they feel their denial fails, they experience loss of control and helplessness. Pilots exposing these reactions over time are not fit for flying. After an accident such feelings may develop as a result of long periods of emotional stress which refer to untreated reactions. These changes are slow but one can begin to perceive them in cockpit as incomplete or late briefings, distraction, poor resource management and anxiety. When the pilot exhibits subtle signs of withdrawal, loss of humor and fatigue our awareness and alertness towards the problems should increase. It is possible to prevent emotional stress reactions from being permanent and destructive by teaching avaitors and staff in charge proper debriefing procedures after a crash.

The way to perform a psychological debriefing after an accident varies from culture to culture and nation to nation. It is not advisable to buy a debriefing program from another air force, because what is recognized as proper reactions in one culture may be looked upon as reactions not compatible with the typical aviator behavior in another culture. The important issue that each flying unit has a program which functions when an accident has happened. Just a slap on the shoulder from the flight surgeon after the physical examination and good luck wishes, may be fatal when the aviator after approximately two years time starts feeling odd, having reactions of anxiety, fatigue and aggression that can not be explained from his present situation.

When I became interested in this field twelve years ago, the first case I was confronted with was a pilot that had ejected successfully from an F - 16. He had no physical injuries and was encouraged to continue his flying program as soon as possible after the accident investigation board had finished its inquiries. Everything seemed to be fine and the pilot performed his job apparently in the same way as prior to the accident. After some time he developed fear of certain flying programs. Prior to the accident he was social and outgoing, but this changed and he became aggressive and retreated from the squadron's social life. All these symptoms developed so gradually that he himself was not aware of the changes in his personality that had taken place. His denial of the facts was so successful that he did not obtain intimate contact with his own emotions. What made him consult to the Institute of Aviation Medicine was his lack of physical well beeing. He complained about chest pains and digestion disorders. After a thorough medical examination it was concluded that he was physically fit for duty, but that his problems might be emotionally based. After several consultations it became apparent that his complaints had gradually

started after the ejection, and that he had tried to repress these reactions out of fear for beeing grounded. Nobody had told him about normal emotional stress reactions after an accident, but everybody kept telling him how lucky he was that not only had he survived the accident, but he did not even have a scratch. This lack of ability to feel grateful disturbed him, so he tried to repress his problems even harder.

The result of this accident could very well have been another incapacitated aviator who received life long waiver. After a number of sessions of psychological consultance including information about normal emotional reaction patterns after critical stress incidents the pilot started on his way back to normal flying duty. Today he is a well functioning pilot.

The ordinary questionnaires to be completed either at the annually medical examination or after an accident or incident contain remarkably few questions about the aviator's mental status.

One of the questions read: "Can you think of any psychological or personal conditions that might have interferred with your flying lately?" Other questions inquire about frequent trouble with sleeping, depression or excessive worry, loss of memory or amnesia, nervous trouble of any sort. Few flight surgeons have been educated in critical incident stress reactions and how they may interfere with the pilot's mental balance, they therefore have a tendency to concentrate on the physiological examination and give the pilot his medical classification based on these results.

With new information about normal emotional reactions after accidents and incidents the teaching program in aviation medicine for both flight surgeons and aviators in the Royal Norwegian Air Force contains instruction in this field. This program has made the aviators more aware of which emotional reactions to be expected after an accident, how long do they last and how to treat them. This instruction has made psychological reactions more accepted and prepared the aviators to look at psychological debriefings as a matter of routine.

The program starts with an overview of which reactions to expect after an accident and what to expect if a psychologically debriefing is not performed. Knowing what are normal reactions makes it easier to accept them and understand that they are appropriate in relation to the extreme stress they have been exposed to. The advantage of performing the debriefing shortly after the incident is underlined. Several of the pilots who have gone through the training program have themselves been in an accident or incident, have reported back that it was not so difficult to accept the typical incident stress reactions when they were prepared for them. They also felt comfortable in discussing these emotional reactions with close relatives or colleagues, instead of keeping them all to themselves.

Each squadron has made its own emotional debriefing program to be put into action after an accident. The program states when a debriefing should be performed to action and who should participate. After an accident also next of kin should be included, in order to make them aware of normal reaction patterns in their spouses and thus inform them of the importance of their supportive role in the stress reaction process. Ideally this debriefing program should be run by the squadron itself, thus underlining that the reactions to come are quite normal. However, there should always be a flight surgeon or a flight psychologist close at hand in these sessions in order to releave the squadron leader of some responsibility, and also to act as a safety valve in case this is needed..

In the flight surgeon's education they are taught to be especially aware of psychological and somatic reactions after accidents. They are also made aware of their responsibility to follow up aviators who have been affected by incidents and accidents.

Since this program has been activated the pilots have appeared fit for flying as soon as they have been released by the accident investigation board. They should, however, be made aware that they will experience a slower progression in their training program than normal in the first six months to come, and also that their cognitive capacity may be reduced in this period.

In addition they we teach them that the initial reaction to accident stress is a sense of unreality. Somebody may also have a strong feeling of inner emptiness. It is difficult to fully grasp what really happened. Gradually the sequence of events will however sink in, and it is at this stage that the strongest reactions manifest themselves. Anxiety is one of these reactions. It is often accompanied by uncomfortable restlessness and may cause somatic symptoms like shivering, sweatning, palpitations, pressure in the chest nausea and tensions in the body, just like the experiences of the pilot I referred to in the introduction of this paper. Many pilots will thus blame themselves and feel guilty for having survived when their collagues lost their lives. It becomes difficult for them to consentrate on functioning adequately, both at work and at home.

Another reaction that are easy to recognize are the sleep problems. Falling asleep may be difficult, or the sleep may be disrupted due to repeated wakenings during the night. Dreams may also contribute to

disturbing sleep and make the person wake up early without feeling rested.

Some people may feel a need to be alone and may easily withdraw from contact with others. They wish to protect themselves against everything that could revive or reinforce the strong distressing feelings. Such reactions are understandable, but should not be accepted, because the way back to normal social and work related environments may be difficult and some people will need treatment.

So far this program has demonstrated two effects

A) Maintaining the confidence level the aviator had prior to the accident, and

B) Demystifying normal emotional reactions in flying personnell, which in itself is a very important accomplishment.

In conclusion: the pilot is fit for flying when he has been made aware of the emotions connected with an accident and what to do if and when they appear. The pilot will be able to continue his duties if he has a supportive team that he can lean on in the first period of time after his traumatic experience. For most people it is an advantage to get back to work and resume the normal activities as soon as possible The aviator will be able to excecute his duties without limitations, knowing that the emotions he has gone through are normal and expected, provided the flight surgeon has performed this part of his job carefully

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The Concept Of Aeronautical Adaptability As Developed By The U. S. Navy

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SUMMARY

Physicians working in the field of aviation medicine have known from the earliest days of the specialty that the psychological fitness of aviators was a critical element in minimizing aircraft accidents. Studies, spanning 8 decades of aviation, have demonstrated that the majority of aviation accidents have been the result of human factors. Selection of psychologically fit candidates and monitoring the status of designated Naval Aviation personnel has thus been one of the major tasks performed by Naval Flight Surgeons. To guide them, the concept of Aeronautical Adaptability has been developed. Composed of two similar but separate concepts, the first one requires the flight surgeon to evaluate the motivation, temperament, flexibility, and appropriate psychological defense mechanisms of aviation candidates. The second concept accepts that once designated, an aviator has proven his ability to adapt to the rigors of aviation. Still, it requires monitoring of the experienced aviator's pattern of coping with the stresses of aviation, and provides the means to find designated personnel Not Aeronautically Adaptable should maladaptive behavior affect the safety of flight. This paper will explore the early psychological standards in the U.S. Navy, then discuss Aeronautical Adaptability as it evolved over the last 15 years. It will discuss the rational behind the current concept and show how Aeronautical Adaptability provides a fair, timely system of review to help the U.S. Naval Flight Surgeon process difficult cases that could present an unacceptable safety risk in Naval Aviation.

1. EARLY STANDARDS

Flight surgeons have faced the challenge of selecting qualified flight training candidates from military aviation's earliest days. Initial physical standards were simple, filling less than two pages (1). While any physical defect was grounds for rejection, physicians working in the field of aviation medicine before World War One paid little attention to the psychological qualifications of the applicants. Flyers of that era were often "considered 'fools' and 'crazy' (2)." The 1912 directive from the Army Surgeon General on aviation selection made no mention of a candidate's personality or psychological status (3). Later that same year, the Navy largely copied the Army standards when creating Naval Circular Letter No.125221 titled *Aviation Duty: Physical Examination of Candidates.* The only significant addition to the Army's directive, was a single line stating, " ... any candidate whose condition shows that he is inclined to any excess that may disturb his mental balance or to alcoholism, should be rejected (1)." Applicants were accepted provided they had enough nerve and passed the newly developed aviation physical examination (4).

Early physical standards were stringent. Responding to reports from Great Britain that "Ninety of every 100 British aviators killed during this period died because of their own individual deficiencies and of these, 60 were found to have been directly due to physical defects (5)," American flight surgeons created physical standards to ensure that "no aviator shall fail in his mission because of discoverable physical defects (6)."

Not all believed such ideal standards were necessary. Assistant Surgeon R. P. Parsons was the first Navy physician to document his dissent. In April, 1918, Dr. Parsons wrote: "Our Navy has already rejected hundreds of applicants because of trivial minor defects, most of whom, it is safe to say, could have become successful aviators (7)." Troubled that too many of these "perfect health" men were unable to complete flight training, he became "convinced also that there is a *something else,* whatever it may be, worthy of investigation, and which should be deemed fully as important as a physical examination for use as a criterion by which men are to be selected or rejected in the recruitment of student aviators." By questioning experienced flight instructors, he hoped to identify "the most essential qualities contributing to the making of a successful aviator." To a man, those surveyed identified: "(1) Coolness under strain, (2) Dependableness to always do the correct thing at a critical moment; (3) Mental and physical alertness;

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(4) Lack of any inherent fear of being in the air; and (5) Persistence and perseverance in his ambition" as the ingredients necessary "to become a successful aviator."

The instructors disagreed on whether "the temperamental type of extreme stolidity or that of great nervous energy" was the preferable personality style for the ideal student. Parsons devised 10 clinical tests to determine if the instructors' opinions were valid and predictive of a candidate's flying ability. Testing 250 students, he found 2 tests that he believed had some validity, 3 were of no use and insufficient data was available on the other 5. He concluded that more work was needed to standardize tests that could be used to supplement physical exams, thereby improving the efficiency of the selection process.

2. BEGINNING OF AERONAUTICAL ADAPTABILITY

It would appear that Parson's paper had little effect on the Navy. Standards published in 1922 by Neuberger cited the need to carefully select candidates, stressing the requirements of "mental attitude and physical fitness (8)." Totaling 28 pages, the report frequently mentioned that candidates be "mentally qualified", yet never defined what was mentally qualifying or disqualifying.

In 1927, troubled by the high cost of flight training, the Chief of the Bureau of Aeronautics sent a letter to the Commandant of the Pensacola Naval Air Station, pointing out that part of the expense was due to excessively high student failure rates (9). The Superintendent of Aviation Training turned to his flight surgeons for suggestions.

Lieutenant Commander Louis Iverson, MC, a member of the first Navy class to graduate from the Army School of Aviation Medicine, was already working on the problem. The previous year, Iverson and Lieutenant H. B. Crummes, MC, had implemented a routine method of evaluating the psychological fitness of candidates. Iverson would conduct the physical examination on each candidate, after which Crummes obtained their psychiatric history. Each medical officer would attempt to form a definitive opinion of a candidate's aptitude. Iverson and Crummes then met at the end of the day to discuss each cadet. After assigning a numerical grade predictive of his probable success or failure, the subject's progress in flight school was monitored.

From Iverson's and Crummes early work came the concept of Aeronautical Adaptability (AA). The 1927 edition of the Manual of the Medical Department was the first official Navy instruction to use the term:

> Aeronautical adaptability. Graded from 0 to 4.0. When derogatory impressions are obtained they will be the subject of a confidential letter to the bureau, accompanying the forwarding of Form No. 1. If aeronautical adaptability is graded below 2.5 and if otherwise physically qualified the recommendation will read: "Physically qualified but not temperamentally adapted (10)."

Vague from the outset, the grading scale was designed to be compatible with the Navy's standard 4.0 evaluation system. Missing were criteria upon which to assign values, so flight surgeons used their judgment to grade candidates. AA became an integral part of the Naval Flight Surgeon lexicon in 1927, and has been a required determination on every flight physical, including "winged" personnel, since that time.

Iverson's report to the Bureau of Aeronautics focused attention on the problem. In 1928 Rhoades described the state of the selection process (11). Each candidate received an extensive physical exam, which was followed by a psychological evaluation, consisting of a review of the candidate's life to that point. Memory and reaction time were measured by a word reaction test very similar to one created by Parsons in 1918 (7). From the interview the flight surgeon was to place the candidate into one of three classes of personality characteristics – above average, average, or below average (Table 1). Aeronautical adaptability was the flight surgeon's "prognostication as to whether he will pass or fail the course" (11), taking into account physical, as well as, psychological fitness based on the preponderance of characteristics the candidate had in a given class.

Improvements were being made, but flight surgeons were still troubled by the selection process. Ilkstadt (12), in 1929, and Haselton (13), in 1930, stressed the need for more research into psychological factors. Ilkstadt compared success and failure rates in candidates whose physical findings were close to the limits for disqualification, as compared to students who approached the ideal. He concluded that "(1) *Within qualifying limits*, no correlation exists between physical findings and ability to fly; (2) Such physical findings were no indication of aeronautical adaptability; (3) The physical standards now required are not directed toward adaptability and neither increases nor decreases a student's chances to qualify as a pilot; and (4) Aeronautical Adaptability must be determined through neuropsychiatric examination (12)."

Haselton's article appeared in the very first edition of *The Journal of Aviation Medicine*, immediately preceding Longacre's classic article on pilots' personalities (14). Discussing the high percentage of failures in both Army and Navy flight training,

Haselton believed that many of these failures were due to, "...the inability of the flight surgeon and medical examiner to determine the psychological equipment for flying of the applicants brought before him for examination (13)." He recognized that a candidate's temperament and personality were important factors in his ability to adjust to the aviation environment. He observed that extremes of either characteristic made success unlikely. Haselton also placed "tics, tremors, or the epiletoid diatheses" outside consideration of one's aeronautical adaptability, "as these are considered physical or psychiatric manifestations and should be divorced from the psychological examination (13)." Haselton was unaware that his opinion accurately predicted the form aeronautical adaptability would ultimately take 50 years later.

TABLE I. RHOADES' PERSONALITY CLASSES

Above Average	Average
Cheerful	Sober
Aggressive	Modest
intelligent	Moderate intelligence
Precise	Moderate precision
Quick	Average
Retentive	Moderately retentive
Controlled	Moderately controlled
Attentive	Moderately attentive

Below Average
Depressed
Submissive
Stupid
Vague
Slow
Not retentive
Restless
Inattentive

3. AERONAUTICAL ADAPTABILITY OF THE 1930's

Responding to these reports, the Bureau of Medicine and Surgery sent Captain D.G. Sutton, MC, to Pensacola to analyze selection criteria (9). A psychiatrist, Sutton developed an extensive interview composed of psychiatric history, personality study, and psychological tests. In 1931 and 1933, Lieutenant C.G. De Foney, reported the results of two studies of 628 and 677 individuals respectively, which Captain Sutton had initiated (15, 16). De Foney concluded that unstable individuals, which Sutton defined as the, "self-conscious, sensitive, introspective individuals with frank neurotic tendencies and the unstable extrovert with his unmistakable compensatory reaction of well being (15)" should be eliminated from training. Positive predictive factors for success were stability, aggressiveness, and courage, while intelligence, concentration, and reaction time had little predictive value.

As a result of the efforts of Sutton, De Foney, and others, the 1937 Manual of the Medical Department definition of AA was changed to:

> Aeronautical Adaptability: After the examination has been completed, the examiner shall make an assessment of the individual's qualifications for flying, based upon the physical findings and the result of the neuropsychiatric examination. While no individual will possess all good traits, or all bad ones, the examiner will summarize his impressions of the individual's aeronautical adaptability which shall be recorded as favorable or unfavorable. Where an individual is found to be physically qualified but his aeronautical adaptability is regarded as unfavorable, the entry of findings on NMSAv Form 1, as finally recorded, shall be "Physically qualified, but not aeronautically adapted." (17)

Following De Foney's work, others sought methods to predict a candidate's future success. One of the more interesting attempts of the 1930's was the use the Schneider Index as a selection criteria. Developed by Dr. Edward C. Schneider in 1920 (18), this cardiovascular rating was used extensively by both the military and Civil Aeronautics Administration to detect chronic fatigue and exhaustion in aviators. The Army reported 106 applicant disqualifications in 1936 for failure to achieve adequate scores (19). In 1938, Lieutenant (Junior Grade) W. O. Fowler, MC, reviewed 1,021 consecutive records of Naval Aviation Cadets at Pensacola, comparing their Schneider score and success in flight training. He concluded, "In general, there is no correlation between the Schneider Index and a person's ability to fly (20)."

Along more traditional lines, Lieutenant Commanders R. H. White, MC, and V. S. Armstrong, MC, continued to define traits that were predictive of success or failure (9). Factors they correlated with success were strong motivation to fly, graduation from college, and good judgment. Failure was predicted in those indifferent to aviation, those with no education beyond grade school, or those with evidence, by history or examination, of emotional instability (21).

In 1939, the Civil Aeronautics Administration asked the National Research Council to form a committee to research the process of selecting aviators (22). The Navy was represented on the Committee on Selection and Training of Aircraft Pilots from its inception (9). As early as 1940, the Navy started screening Naval Aviation Cadets with early forms of the pencil and paper psychological

> Before selection, candidates are to be interviewed by the flight surgeon for evidence of early interest in aviation, motivation to fly, absence of motion sickness, and practical appreciation of flight beyond childhood fantasy. Evidence of positive coping skills and good interpersonal relationships should be thoroughly evaluated (28)."

Completing flight school was considered proof of an individual's ability to adapt to the aviation environment. Designated aviators were therefore considered Aeronautically *Adapted*:

> "Those having demonstrated the ability to utilize long term appropriate defense mechanism and displaying the temperament and personality traits necessary to maintain a compatible mood, suppress anxiety, and devote full attention to flight safety and mission completion (28)."

DSM-III significantly changed the way Naval Flight Surgeons approached the problem of defining aeronautical adaptability. Prior to its publication, the focus of the Navy's selection process was to identify traits predictive of a candidate's success. Longacre's classic study provided a list of favorable traits that an aviator might possess, and led to creation of the ARMA, still used by the U. S. Army and Air Force to select candidates (24). Navy, Army, and Air Force researchers have tried for years to divine the magic combination of physical, psychological, and personality traits that would guarantee success in military aviation. The trouble with that approach is that the requisite characteristics of the ideal aviator have long been elusive

Under the Navy's current concept, during the initial physical examination flight surgeons strive to identify characteristics that would prevent a candidate from completing training. This model assumes that a properly motivated candidate, possessing normal temperament, flexibility and defense mechanisms will be able to suppress any anxiety associated with flight training, and devote his/her full energies to completing the program (28). It should be noted that few Student Naval Aviators (SNA) would be able to discuss the concept of suppression as a defense mechanism for flight related anxiety, yet they are taught early in their flying career of the need to leaving distracting issues on the ground by focusing on the task at hand or "compartmentalizing".

Should the individual's psychological defense mechanisms prove inadequate to deal with the stresses of flight training, the model predicts that dysfunctional behavioral patterns will appear. These patterns include poor performance, training difficulties, poor stress coping, flight anxiety, difficulty with crew coordination and/or interpersonal relationships, or an inability to deal with the normal stresses of life. Students exhibiting such behaviors invariably present to sickcall, either through self-referral or when directed by their instructor. Evaluation follows the cookbook approach of DSM-IIIR (29). An Axis I diagnosis would result in either temporary or permanent physical disqualification (NPQ), depending on the prognosis. Axis II Personality Disorders or maladaptive personality traits that preclude continued satisfactory performance in the aviation environment, even though short of meeting the criteria for a disorder, would led to disqualification as not aeronautically adaptable (NAA).

The model for designated aviators makes the same assumption that Caveny made in 1945 when he described fleet aviators as: "the stablest of the stable (25)." Those aviators presenting with situational stress, anxiety, poor coping, or other problems of a perceived psychological / psychiatric nature would initially be NPQ pending appropriate evaluation.

An aviator with an Axis I diagnosis would be treated as is a candidate with a similar diagnosis, except the potential for the designated aviator to receive a waiver is greater (30). An aviator with an Axis II diagnosis is more difficult to deal with. Rarely is an individual with a true personality disorder able to complete flight training given the stress levels involved. A few do. What challenges the flight surgeon then is deciding if the pattern of maladaptive behavior is chronic, and if it interferes with safety of flight, crew coordination, or mission completion. Given the large investment the Navy has made in training an aviator, all cases involving designated individuals must be referred to NAMI's Department of Psychiatry for evaluation (28).

Motivation, performance and technical ability have yet to be mentioned. Under the current concept, designated personnel whose motivation, aviation skills, attitude, or flight safety record are found wanting are referred to an administrative board to determine their fitness to continue in aviation. Medical opinions regarding whether an individual is PQ / NPQ and AA / NAA are considered by the board, but are not a bar to administrative action even if they are diagnosed as NPQ or NAA.

6. SUMMARY

It is interesting to note that the Army's and the Navy's psychological standards developed along parallel but largely separate courses. That is not surprising when one considers that during the period of 1919-1926 and again in 1936-1939, 56 of the first Naval Flight Surgeons trained alongside their Army counterparts at the Army School of Aviation Medicine (31). Still service differences existed then and persist today. The Army and the Air Force currently use the Adaptability Rating for Military Aeronautics (ARMA) to guide in the selection of candidates (24). The Navy uses a

similar concept termed Aeronautical Adaptability (AA), which is broader in scope as it applies to both candidates and designated aviators each time the flight surgeon interacts with them.

Advantages the Navy's concept of Aeronautical Adaptability offers include:

(1) Model directly correlates with DSM–III–R and Secretary of the Navy nomenclature separating physical and nonphysical disorders.
(2) Provides a method of disqualifying individuals based on their impact on safety of flight.
(3) Uses established criteria to categorize behavior, helping to standardize results.
(4) Provides a fair system of review of potentially controversial cases.
(5) It is easy for Student Naval Flight Surgeons to conceptualize.
(6) It uses terminology that has been in place for over 60 years – it is accepted and it works.

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VESTIBULAR EXAMINATION IN PILOTS SUSCEPTIBLE TO MOTION SICKNESS

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1. SUMMARY

An analysis is presented of data obtained from vestibular examinations on student pilots prone to airsickness. It is shown that those pilots who were most susceptible during the initial flight training course, in the laboratory even suffered from mild conditions of the Coriolis test. Abnormal postural behaviour in the tilting room test, or long time constants of the nystagmus decay after sudden stops from constant velocity rotation, do not contra-indicate a succesful desensitisation programme. A Practical Flying Selection considerably diminishes the number of student pilots suffering from airsickness. Those who passed this test, but got nevertheless into motion sickness trouble during the pilot training, were succesfully treated with a desensitisation programme.

2. INTRODUCTON

Motion sickness may be induced by moving around in another way than during normal walking. It is therefore not surprising that, dependent on the flight profile, crew and passengers of civil and military aircraft sometimes suffer from motion sickness. Motion sickness may become a serious threat when the pilot is incapacitated to do his duty because of motion sickness. So it makes sense to look for selection tests on motion sickness susceptibility. Since it is generally agreed upon that a functioning vestibular system is required in order to get motion sick, much effort has been put into the research on vestibular tests for selection on motion sickness susceptibility. Several tests have been described in the past [1-3], but the validity of these tests is equally often questioned [4].

In practice it turns out that most student pilots who experience motion sickness overcome their problems after some flights by adaptation. However, some student pilots remain suffering from these problems. If their flight performance is affected because of this, the consequence is either suspension from the training, or optionally a special motion sickness desensitisation treatment [4,5]. This depends on the effort an air force is willing to put into their candidates. It is obvious that such a training involves money, especially when a part of the desensitisation training is done in an aircraft.

The objective of the present paper is to give an overview of the approach of the RNLAF to airsick student pilots, with emphasis on the applied vestibular examinations.

2.1 Time History of the Research Programme

Data presented here have been obtained from a research programme on air sickness initiated by the RNLAF in 1983 and carried out by the TNO Human Factors Research Institute at Soesterberg. In 1989 the RNLAF changed the selection procedure for student pilots. Therefore the data set is divided in two parts, one obtained in the period 1983-1988, and one in the period 1990-1993.

In the years 1983-1988 no particular selection on motion sickness susceptibility took place by the RNLAF. If during the elementary flight training student pilots were about to be suspended from the training because of air sickness combined with bad flight performance, they were referred to the ENT Dept of the Vrije Universiteit at Amsterdam. There they were subjected to routine equilibrium tests, and to tests especially directed to obtain information about motion sickness susceptibility. The primary aim of those tests was to isolate any vestibular causes for the students' susceptibility to airsickness. At that time exceptional motion sickness susceptibility did not result in a follow-up in terms of a desensitisation programme. It simply meant the end of a career as a pilot in the RNLAF. The data of this period are presented in section 3 and concern 17 student pilots (data set 1).

From 1989 on the RNLAF introduced in the selection procedure a so-called Practical Flying Selection phase. If during these sorties control of the aircraft was returned to the instructor because of motion sickness, the candidates were out of the selection process. No action was taken to assess the vestibular function as possible cause for their susceptibility to motion sickness. In some candidates who passed this practical flying selection, however, still motion sickness interfered with the subsequent pilot training at Woensdrecht AFB. In those cases the present protocol foresees in a flight surgeon's referral to the TNO Institute for evaluation of the vestibular function, and to the RNLAF Mental Health Dept for evaluation of psychological contributions to the motion sickness problems (personality factors). If both investigations result in a positive advise,

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the flight surgeon can initiate a desensitisation treatment at the TNO Institute. After the desensitisation treatment, the flight surgeon may advise to continue the regular flight training. The protocol does not foresee any new desensitisation treatment in case of reoccurrence of motion sickness during the training afterwards. After 1989 three RNLAF student pilots have been referred to TNO for vestibular evaluation, and finally also for a desensitisation treatment. They all have returned to their normal flight training programme, and motion sickness has not interfered with their career anymore. In section 5 the results of the vestibular evaluation of these candidates is presented together with data from two candidates from civil aviation air schools, who also participated with success in the desensitisation programme (data set 2). Details of this desensitisation programme are presented in section 6.

The data from all student pilots prone to airsickness are compared to data obtained from a control group, consisting of student pilots who passed the Practical Flying Selection, but have not yet started their pilot training. These pilots participate in a longitudinal study in which they will be investigated once more during the training and a third time when they have completed their training. They match well with the motion sick student pilots, apart from proneness to air sickness.

3. SET 1: 1983-1988

3.1 Subjects

Set 1 comprises eighteen student pilots, who were examined on their vestibular function. The majority of these requests came from Elementary Flying Training at Eelde AB: One student was examined because of unusual behaviour during selection in the Spatial Desorientation Demonstrator at Soesterberg, but did not show any unusual susceptibility to airsickness during subsequent training. This means that a total of 17 student pilots suffering from airsickness were examined in that period.

3.2 Airsickness History

Table I shows the stages of the Elementary Flying Training programme at which airsickness was observed in these candidates. The table shows whether any medication (m) was taken during flights and the stage at which the candidate was referred to the University Hospital (U) for examination. Referral is usually closely followed by suspension (S) from the programme. Whenever the Table does not end with an 'S', the student in question was not suspended from the programme and motion sickness did not play a decisive role in his subsequent career.

Table I is ranked in decreasing order of susceptibility to airsickness. Notice that most of the candidates examined start having trouble at the very first familiarization (F) flight, where they are back-seat passengers. Candidates a through e never get over their airsickness. Those that do recover face a new critical phase, starting with training stage 9A when aerobatics is introduced. Two candidates, who initially had overcome this stage, finally had to return to the Netherlands from Sheppard AFB because of airsickness. Candidate r was included in Table I for comparison only: no airsickness was observed during his training. The reason for his examination was his deviant behaviour in the Spatial Disorientation Demonstrator (SDD).

It is not known whether airsickness occurred in other candidates who did complete the course successfully, and if so, how often. Such information is required before the exceptionality or otherwise of the pluses in Table I can be determined.

3.3 Vestibular Tests

The pilots in question were subjected to routine vestibular examination at Amsterdam. This involved electronystagmography as a means of detecting spontaneous or provocation nystagmus. In addition, visual ocular control was tested through measurement of optokinetic nystagmus, smooth pursuit and the ability to suppress vestibular nystagmus by visual fixation. Naturally the test battery included rotation-chair tests and caloric irrigation of the labyrinths (looking for left-right discrepancies which might hamper adaptation). By means of stabilometry, postural control was determined.

A supplementary set of tests looking more specifically at motion sickness, involved tests in a rotating chair-drum combination, and posturography in a tilting room. Decay of vestibular nystagmus slow component velocity was measured after sudden stops from constant velocity rotation (90 dg/s CW and CCW). The rotating chair-drum combination was employed for an Intersensory Coriolis Test (ICT): Determining the effect of head movement on well-being when the visual and vestibular systems are stimulated separately ('vis' and 'ves', respectively), congruently (vis > ves >) or incongruently (vis > ves <). Maximum chair velocity in these conditions was 60 dg/s. The relative drum velocity with respect to the chair was 60 dg/s CW or CCW. In the 'ves' condition the light was switched off in the drum. A final test looked at posture control in the tilting room, a test which has triggered deviant responses in people susceptible to seasickness [6]. The subjective horizontal (SH) is also tested here.

3.4 Test Results

Table II shows the results of these tests. A '-' indicates normal findings. The '+' in the first column indicates an abnormally high spontaneous nystagmus. In the second column 'irr' stands for an irregular optokinetic nystagmus. The caloric irrigation column shows the difference in terms of percentage between the two labyrinths, whereby a discrepancy of 22% or more is considered deviant. The letter 'V' indicates that the test

Table I. Presence (+) or absence (-) of airsickness for each stage of the training programme of the student pilots (a-r). (U) means referral to the Vrije Universiteit.

	F	1	2	3	4	5	6	7	8	9A	9B	10A	10B	11A	11B	12	USA
a	+	+US															
b	+	+U	+	+	+S												
c	+	+	+	+	+US												
d	+	+	+	+	+US												
e	+	-	-	-	-	-	-	-	-	+	+m	+m	+SU				
f	+	+	-m	-m	-	-	-	-	-	+	+m	+US					
g	-	+	-	-	-	-	-	-	-	+	+	+US					
h	+	+	+	-	-	-	-	-	-	-	+	-	+	+	+US		
i	+	+	+	-	-	+	-	+	-	+	+	+	+	+	+	+US	
j	+	-	-	-	-	-	-	-	-	+	-	-	+m	+	+US		
k	+	+	-	-	-	-	-	-	-	-	+	+	+	-	+	+US	
l	+	+	-	-	-	-	+	-m	-m	-m	-	-	-US				
m	-	-	-	-	+	-	-	-	-	-	+U	+	-	-	+	+	-
n	+	+	+	-m	-	-	+	-	-	+	+m	-m	+m	-	+U	-	-
o	+	+	+m	-	+	-	-	-	-	-	+U	-	-	-	-	-	-
p	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	+SU
q	+	+	+	-	-	-	-	-	-	-	+	-	+	-	-	-	+U
r	U -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

induced vomiting; '(V)' indicates near-vomiting. The '+' in the tilting-room column indicates a stronger than normal influence of the tilting visual surroundings on posture control. In the subjective horizontal column the 'x' indicates that, although the subjective horizontal conforms to the objective horizontal, the spread of the individual SH settings is abnormally high. The next two columns show the time constant τ indicating how the slow phase velocity of the nystagmus after a sudden stop decays to zero. The V and (V)s again indicate vomiting and near-vomiting, respectively. Vomiting sometimes precipitated the end (E) of the test. The last four columns show the motion sickness scores according to Graybiel et al.'s criteria for the respective head movements during the different parts of the ICT (1-2 points indicates slight malaise, 3-4 points indicates moderate malaise B, 5-7 points indicates moderate malaise A, 8-15 points indicates serious malaise and 16 or more indicates frank sickness [6,7]). A score of 8 or higher, therefore, signalled the end of the test, sometimes of the whole examination. Empty spaces in the table indicate that not all the tests were run for every candidate, sometimes because of the candidate's condition (candidates a, b, f, l and p), sometimes for other reasons.

The routine vestibular examination did not show any hard 'pathological' abnormalities other than an excessive spontaneous nystagmus (candidate g) and a significant (25%) left-right discrepancy in the caloric irrigation of candidate n. The latter result was found during an abnormally high fluctuation of the vestibular nystagmus, while the optokinetic nystagmus was very irregular as well. The observed values are probably attributable to the fact that the candidate had been called out of the middle of a training exercise to perform the test and had hardly seen his bed for a few days. Indeed, a repetition of the test at a later date showed no sign of vestibular imbalance (6%). One striking aspect of the routine vestibular examination is the high percentage of candidates (approx. 20%) who vomited or nearly vomited during or after caloric irrigation.

From the tests looking more specifically at motion sickness the tilting room examination did not reveal any abnormal behaviour, stabilometry showed only once a more than normal instability, and the subjective vertical was found twice to have a too large standard deviation in the settings.

The time constant of the decay of the nystagmus slow-component velocity as determined after a sudden stop from 90 dg/s, is not enlarged in subjects susceptible to motion sickness compared to the time constants of the control group (see Table III). However, vomiting after such a test is quite unusual and considered as an abnormal reaction.

The outcome of the Intersensory Coriolis Test is noteworthy. Our experience with 'normal' test subjects is that, as a rule, they manage the test battery without severe symptoms of motion sickness, similar to the control group (see Table III). Table II shows high motion sickness scores. It also shows that the pilots did not always go through the complete test battery, because in some cases nausea or frank sickness prompted a suspension of the test. Scoring motion sickness during the congruent visual-vestibular part of the ICT as seen in pilots a, b, d and e is very unusual

Table II. Data found during routine and specific motion-sickness-oriented vestibular tests at the Free University of Amsterdam. The abbreviations are explained in the text.

	spont prov nyst	vis ocul contr	calor perc imbal	tilting room	stab	sh	rot chair τ (s) le	ri	Intersensory Coriolis Test vis> ves>	vis	ves	vis> ves<
a	-	-	11				18	22	16E			
b	-	-	4	-	-	-	15	13	2	8E		
c	-	-	7	-	-	-	18	21V	0	2	2	16E
d	-	-	20(V)	-	-	-	22	24	3			13E
e	-	-irr	18V	-	-	x	14	16	5			15E
f	-	-	10V	-	-	-	22	20VE				
g	+	-irr	3	-	-	-	22	26	0		6	
h	-	-	1	-	-	-	17	20	0	2	2	4
i	-	-	1	-	+	-	27	25	0	1	1	10E
j	-	-	12	-	-	-	15	29	0	1	3	5
k	-	-	12	-	-	-	21	17	0			16E
l	-	-	18	-	-	x	22	20	0	5	9E	
m	-	-	9	-	-	-	16	17	0	1	1	2
n	-	-irr	25/6	-	-	-	12	14	0	3	5	5
o	-	-	9	-	-	-	12	17	0		1	
p	-	-	8(V)	-	-	-	22	23VE				
q	-	-irr	10	-	-	-	12	12	0	2	4	5
r	-	-	n.a.	n.a.	n.a.	n.a.	14	23	0	0	0	2

(see also Table III): Even one single head movement was sufficient to cause vomiting, as was the case with candidate a. For half the sixteen candidates the Intersensory Coriolis Test marks the premature end of the examination. Notice that the (relatively) most serious cases are found near the top of Table II, which conforms to the decreasing susceptibility to airsickness shown in Table I.

4. CONTROL GROUP

4.1 Subjects

Twelve student pilots, who had passed the Practical Flying Selection, but had not yet started the pilot training were subjected to a large vestibular test battery at the TNO Institute, as part of a longitudinal study on the changes of the vestibular parameters in the course of a flying career. They are of the same age as the referrals, and match quite well, because they have passed the same pilot selection. In this paper only those tests are presented which are of interest for comparison with the data from the airsick student pilots.

4.2 Results

In Table III the results obtained from the control group are shown. Only once smooth pursuit was found to be not optimal, the other data did not show any abnormalitites. Notice the low scores on the ICT.

5. SET 2: 1990 -1993

5.1 Subjects

In line with the expectations due to the inclusion of a Practical Pilot Selection phase in 1989, motion sickness was seen less frequently by the RNLAF. Three student pilots were referred to the TNO Human Factors Research Institute in this period. All three candidates took part in the desensitisation training (see section 6). During this time two civilian student pilots troubled by airsickness were submitted to the same tests and took part in the desensitisation course as well.

It is difficult to rank the severity of airsickness susceptibility for these five subjects and to include them in Table I because of different training histories.

5.2 Vestibular Tests

In this period the vestibular examination took place partly at the Vrije Universiteit and partly at the TNO Human Factors Research Institute. Besides the Intersensory Coriolis Test, the Coriolis Stress Test (CST) was added to the test battery. This test requires head movements from upright to 90 dg forward inclination and back again at two seconds intervals for 120 s during 90 dg/s CW rotation, for 120 s during 90 dg/s CCW rotation, subsequently for 180 s during 180 dg/s CW rotation and finally for 180 s during 180 dg/s CCW rotation. The test is stopped either when the subject has to vomit, or when the subject prefers to stop.

Table III. Test results of 12 student pilots who passed the practical flight selection, but who had not yet started the flight training.

	spont prov nyst	vis ocul contr	calor perc imbal	tilting room	stab	sh	rot chair τ (s) le	rot chair τ (s) ri	Intersensory Coriolis Test vis> ves<	vis	ves	vis> ves<
1	-	-	n.a.	-	-	-	18	12	0	n.a.	0	n.a.
2	-	-		-	-	-	12	14	0		0	
3	-	+		-	-	-	14	12	0		0	
4	-	-		-	-	-	26	26	0		0	
5	-	-		-	-	-	20	22	0		0	
6	-	-		-	-	-	20	17	0		1	
7	-	-		-	-	-	18	18	0		0	
8	-	-		-	-	-	11	10	0		0	
9	-	-		-	-	-	16	13	0		0	
10	-	-		-	-	-	23	18	0		0	
11	-	-		-	-	-	9	9	0		0	
12	-	-		-	-	-	26	14	0		0	

5.3 Results

The results of the examinations are presented in Table IV. Some tests revealed abnormalities, but the scores of the Intersensory Coriolis Test are moderate compared to the data set of Table II. The results of the Coriolis Stress Test are given as well: Shown is the total time the subject has performed head movements, so the maximum score is 600 (see also Fig. 1).

6. DESENSITISATION

In 1974 Dobie introduced a successful training programme in the RAF which was aimed at boosting resistance to cross-coupled Coriolis stimuli, and the technique is still applied with (85%) success today [5,8]. This desensitisation programme has been cribbed, and a stripped version of it is now offered in the Netherlands. While the British treatment comprises three subsequent stadia (a one week assessment phase, a 4 week ground phase and a 3 week flying phase), the Dutch program consists of one week ground training (one day familiarisation and 3-5 days of training), whereafter the students are supposed to continue flight training without motion sickness problems. Up to now, despite this parsimony, the five student pilots who were recommended to the desensitisation programme, responded well.

The treatment is based on frequent stimulation of the vestibular organ with the same kind of "improper" patterns of movement as do appear in the flight situation. After a theoretical description of the anatomy and function of the human vestibular system, and a thorough explanation of the genesis of motion sickness, particularly vestibular functioning in practise is demonstrated. Not in the air, but plain on the ground. With simple tools (a common turning chair), but also with sophisticated stimulus apparatus (3D-rotating chair, tilting room, horizontal and vertical oscillators). This demonstration quickly proves the pilot in which situations symptoms of motion sickness are to be expected and in which not,

Table IV. Results of the vestibular tests of the five student pilots examined in the period 1990-1993. see for the lay-out also Table III. CST stands for Coriolis Stress Test.

	spont prov nyst	vis ocul contr	calor perc imbal	tilting room	stab	sh	rot chair τ (s) le	rot chair τ (s) ri	Intersensory Coriolis Test vis> ves>	vis	ves	vis> ves<	CST (s) before desens
A	-	-	5				19	17	0	0	0	0	410
B	+	-	19	-	-	-	22	26	0	2	4	9	280
C	-	-	n.a.	-	-	-	19	17	0				60
D	-	-	n.a.	-	-	-	12	12	0	0	0	0	300
E	-	-	5	+	-	-	12	20	0	0	3	6	270

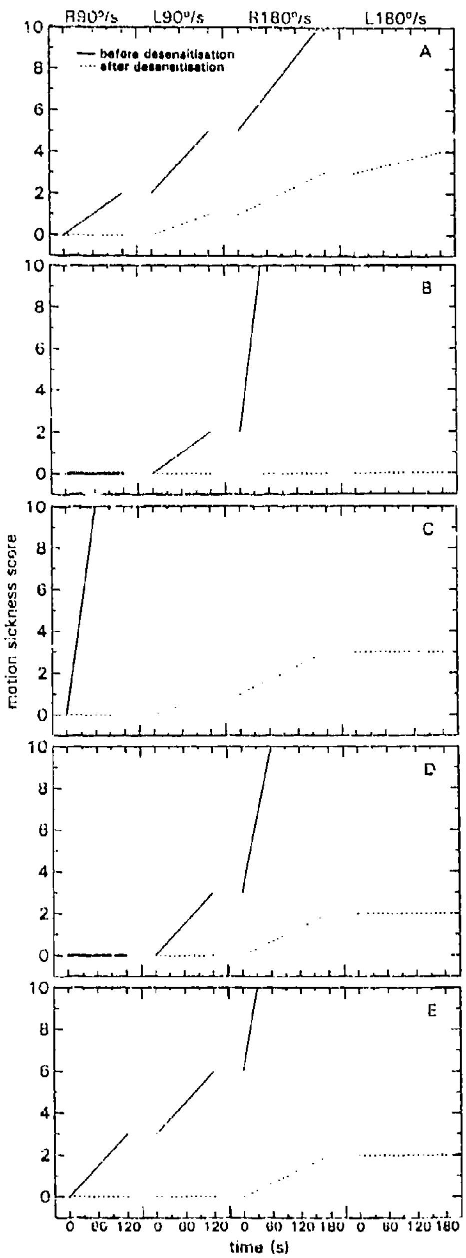

Fig. 1. Coriolis Stress Test results (see text).

and even more important, that what in his mind seems to be a very complex and diffuse matter could be reduced to *one* simple cause. After being familiarized this way, the proper training commences. During the treatment subjects undergo twice a day sessions of cross-coupled stimulation, in a progressive order over the days (being blindfolded and seated on a rotating chair (angular velocity: 30-180 dg/s), while performing head movements to the shoulder or knees, and back). During this bizarre stimulation the student has to perform some common flight related tasks, or has to deal with sudden "emergency" procedures.

The student pilots treated this way were able to perform the mentioned type of headmovements for half an hour or more during rotation at 60, 90 and 135 dg/s, and finally to achieve the complete Coriolis Stress Test without problems. In Fig. 1 subjective motion sickness scores on the four conditions of the CST are shown, before and after the desensitisation treatment (0 = no problems, 1 = dizzy, 2 = stomach awareness, 3 & 4 = epigastric discomfort, 5 & 6 = moderate nausea, 7 & 8 = severe nausea, 9 = queasiness, 10 = vomiting). In order to accomplish an optimal transfer, the regular flight training at Woensdrecht AFB was continued immediately after the ground training had succeeded.

An evaluation of the programme yielded the importance the students attached to the familiarisation phase of the treatment. Presumably, the regular education felt short in this respect (the explanation and demonstration of the relation between human sensory systems, and disorientation and motion sickness).

7. DISCUSSION

Evaluation of the nystagmus and posturographic data reveals that it is hard to select parameters which correlate with susceptibility to motion sickness. This was surprising, because, for instance, a former study on seasickness revealed that tilting room examination and stabilometry showed more postural instability in subjects who were susceptible to seasickness, than in subjects who were immune to seasickness [6,9]. The present data do not support this observation for subjects suffering from airsickness, though. Only two subjects showed a visual dominance in weighting the visual-vestibular information during the tilting room examination and stabilometry was always normal.

The caloric examination did not reveal significant predominances. However, vomiting occurred with a higher percentage than usual in clinical examination (about 5 %), even if we discount the instances of near-vomiting.

The time constant τ appears also useless to discriminate between the susceptibles and non-susceptibles to airsickness (cf. Table II, III and IV). The time constant may decrease with increasing flight experience as has been described in the past by several authors [2,10], but apparently such a difference is not yet visible at the intake. More information will become available when

the pilots in the longitudinal study have been examined again, i.e. when they have finished their training and are placed in an operational squadron. It should be noted that the values of τ show some variation: They are reproducible, however, but a variation in τ of about 5 s is normal, dependent on the level of arousal and the applied nystagmus analysis.
So these tests are not sensitive enough to discriminate for this motion sick group.

The outcome of the Intersensory Coriolis Test is more promising in this respect. Our experience with 'normal' test subjects is that, as a rule, they manage the ICT quite well, i.e. without severe symptoms of motion sickness [11]. This was also found in the present control group (see Table III). A general observation is that subjects experience almost no signs motion sickness when they make head movements during the congruent visual-vestibular part of the ICT [12,13] (see also Table III). So it is all the more striking when a single head movement suffices to cause vomiting, as was the case with candidate a. From Table II we learn that the most vehement reactions on the ICT are found in the upper part, which concerns exactly those pilots who were also the most prominent sufferers from motion sickness during their training according to Table I.

The data from Tables II and IV show that vomiting occurred primarily during the caloric irrigation and during ICT and CST. Also, occasionally, it happened after the sudden stop from constant velocity rotation. This is in line with our current concept about the genesis of motion sickness: Motion sickness may originate if the perceived subjective vertical does not correspond to the expected vertical [14]. In Fig. 2 separation of the gravitational acceleration vector (Subj. Vert.) from linear accelerations (Lin. Acc.) is modeled by transformations (T and T^{-1}) of input accelerations (Lin. Acc. and Ang. Acc.) on the basis of canal and otolith information and low pass filtering. Discrepancies between the subjective and expected vertical (Exp. Vert.) may provoke motion sickness.

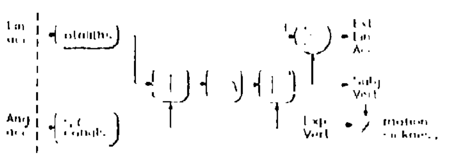

Fig. 2. Concept of motion sickness genesis (see text).

This concept explains the different scores on the congruent and incongruent part of the ICT in a similar way as Guedry and Benson [15] explained the differences in motion sickness scores, obtained during head movements made at a particular angular velocity, but with different preceding vestibular stimuli. They stated that the Coriolis effect is minimally disturbing as long as the resulting rotation vector is parallel to the otolith stimulus. In the congruent visual-vestibular part of the ICT from our test the vectors are also parallel, which explains the low scores. However, since some pilots score motion sickness in that condition, it means that their systems interprete the vectors as being *not* parallel, suggesting that the visual-vestibular interaction is not performed appropriately. The same holds for the sickness after the sudden stop of constant velocity rotation: In that conditon the angular velocity vector is parallel to the otolith stimulus. So in case of vomiting, the data handling must have been inappropriately (vectors *not* parallel). Therefore, motion sickness in these situations is a very strong sign of inadequate information handling of the equilibrium system. In our view this should be a counterindication for a possible desensitisation.
Based on the experience of many years the RAF obtains a success score of 85% with their desensitisation programme [5]. One could argue that a selection test on motion sickness would be usefull if it were possible to detect beforehand those 15% which do not respond to desensitisation training. The approach of the RNLAF since 1989 is apparently successfull in this respect. Almost no motion sickness was encountered after the introduction of the Practical Flying Selection, and those who suffered could return to the pilot training after a desensitisation treatment. The number of airsick pilots (i.e. those referred to the TNO Human ... tors Research Institute) has decreased considerabl... introduction of the Practical Pilot Selecti... suggests, however, that the eventual success... have been lost too. But, as long as there a... candidates, this doesn't matter.
Although it is not proven that the studen... through c (or f) would have failed in the desen... programme, it is tempting to conclude ... Intersensory Coriolis Test as described here c... as a selection test in order to get rid of the airsick student pilots who do not respond to a desensitisation training beforehand. After all, the ICT is done in 15 minutes, and is cheaper than participation in the Practical Flying Selection.

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THE NAMI SYNCOPE TEST BATTERY AND CLINICAL DECISION-MAKING IN AVIATORS WITH SYNCOPE

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SUMMARY

The Syncope Test Battery (STB) was adopted in 1988 at the Naval Aerospace and Operational Medical Institute (NAMI) to provide a coherent and consistent methodology for the evaluation of physiologic or secondary syncope. Records from 1988-1992 that utilized the STB were reviewed, and STB results were compared against final diagnostic categories of physiologic or secondary syncope (n=55). Analysis of the STB showed a sensitivity of 20.6 %, specificity 100 %, predictive value positive 100 %, predictive value negative 43.8 %, and concordance 50.9 %. These results failed to support the effectiveness of the STB, and the STB did not result in any change between the preliminary and final diagnoses as made on other clinical bases. The evaluation and disposition of syncopal aviators is reviewed in the light of general and aerospace medical literature. It is concluded that the STB is not a useful tool in evaluating syncope in the US Navy aviation population. A step-wise algorithmic approach is recommended for the evaluation of syncopal aviators, but the eventual disposition must still be individualized and remains problematic for the flight surgeon.

1 INTRODUCTION

Because syncope has potential dire consequences if it occurs in an aviator during flight, syncope has been an important and problematic issue for the flight surgeon. Interest has long been expressed in both the evaluation of the aviator with syncope and the relative importance of syncope as a causative factor in aviation mishaps.[1] In the late 1980's, the Internal Medicine and Neurology Department at the Naval Aerospace and Operational Medical Institute (NAMI) in Pensacola, Florida, became dissatisfied with NAMI's prevailing clinical approach to US Navy aviation personnel with syncope. This dissatisfaction stemmed from several roots. First, diagnostic and clinical evaluations on required aviation physical examinations and waiver requests were inconsistent in depth and quality. Second, no common conceptual framework existed to facilitate case discussions between NAMI and operational flight surgeons and on which to base training of flight surgeons. Third, aeromedical disposition recommendations forwarded to the line community needed to better reflect a rigorous, objective and scientifically valid procedure that ensured clear communications and affirmed the flight surgery community's commitment to the operational goals of Naval Aviation. Therefore it was felt that a more coherent and consistently applicable methodology for the workup of syncope was needed.

The result was the adoption of a standard procedure for evaluating syncopal aviators that consisted of a set of required clinical tests. Called the NAMI Syncope Test Battery (STB), the goal was to provide reliable evidence in support of the evaluation of syncope as either due primarily to exaggerated physiologic responses or secondary to other primary diagnoses.[2] Use of the STB began in 1988 and was required for all evaluations of syncope in aviation personnel preformed either at NAMI or in the fleet.

By 1992, it was clear that the general medical literature supported moving away from a "shotgun" approach to a more focused, step-wise workup of the syncopal patient.[3,4] This reinforced the impression of the NAMI Internal Medicine and Neurology Department that the STB may not have performed as effectively as originally hoped. The purpose of this paper is to present the findings and

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implications of a retrospective study conducted to evaluate the effectiveness of the STB in the workup of syncopal aviation personnel.

2 METHODS

Subjects: Potential subjects were all patients seen at the Internal Medicine and Neurology Department at NAMI from 1988 through 1992. This pool consisted of nearly 2000 records. The department's appointment database of these records was reviewed to identify patients seen for the single purpose of administration of the STB. To avoid missing potential subjects, all patients seen for syncope, loss of consciousness or syncope-related diagnoses were also identified. From this latter pool, individual records were reviewed to ascertain which patients had actually been given the STB. Patients were entered into the study if, in addition to having had the STB, the clinic chart contained adequate information regarding basic demographic data, the patient's referral and final diagnoses, and the recorded results of the STB. Because of the retrospective nature of this study, no informed consent was required.

Syncope Test Battery: Each study subject had the complete STB performed at the time of their evaluation per the protocol in Table 1. The content and design of the STB was focused toward identifying individuals who may have had syncope due to orthostatic, hyperventilation, vagal or Bezold-Jarisch reflex mechanisms in response to physiologic stimuli. The STB was defined as being "positive" if *any* one of the tests in the battery were positive. Positive endpoints could include reproduction of the patient's pre-syncopal symptoms, frank syncope, dysrhythmias or a significant drop in blood pressure.

Methods: The clinic chart for each patient was reviewed and data recorded based on a pre-determined protocol. Demographic data included age, gender, rank status (enlisted or officer), and aviation status. Aviation status was considered positive if the patient was serving in either a designated aviation billet or an aviation training billet. The patient's syncope or syncope-related diagnosis, as well as other relevant diagnoses, were recorded. Based on final diagnosis, each subject was categorized as having a physiologic syncopal event, or secondary syncope. The physiologic syncope group included all types of syncope considered due to exaggerated physiologic responses (vasovagal, vasodepressor, neurocardiogenic, hyperventilation, micturition, cough/sneeze, Valsalva, et cetera). The secondary syncope group included all subjects with an identifiable disease process felt clinically to be the proximate cause of the syncope (history of closed head trauma with loss of consciousness, coronary artery disease, cardiac conduction disturbance, seizure disorder, metabolic disorder, benign paroxysmal vertigo, disorientation/disequilibrium, psychiatric disease). Special attention was paid to the original referral diagnosis, noting whether it differed categorically from the final diagnosis on the basis of syncope category (physiologic or secondary), and whether the STB results accounted for the difference.

Analysis: Epi Info Version 5.01b statistical software was used for data base creation, data

Table 1. Elements of the NAMI Syncope Test Battery.

SYNCOPE TEST BATTERY

These tests are to be performed by the Flight Surgeon with the patient on electrocardiographic monitoring. Blood pressure and heart rate/rhythm are recorded after each stimulus.

Orthostatic testing:
- Horizontal
- Vertical
- Horizontal for 15 minutes, then vertical
- Inverted head down
- Squatting-to-standing

Provocative testing with patient in vertical or standing position):
- Unilateral carotid massage (15 seconds)
- Bilateral ocular pressure (15 seconds)
- Breath holding at maximal inspiration (60 seconds)
- Valsalva maneuver (30 seconds)
- Hyperventilation (3 minutes)
- Cold pressor test (hand in ice water for 1 minute)
- Positive pressure breathing (3 minutes), for tactical aircrew only

Significant findings (positive syncope test battery):
- Patient's symptoms reproduced
- Asystole for 3 seconds or longer
- Malignant dysrhythmia
- Loss of consciousness
- Orthostasis: 25 mmHg drop in systolic blood pressure, or 10-25 mmHg drop in systolic blood pressure when systolic blood pressure below 90 mmHg

Table 2. Analysis of Syncope Test Battery in the Diagnosis of Syncope.

		Final Syncope Diagnosis		
		Physiologic	Secondary	Total
Syncope Test Battery	Positive	7	0	7
	Negative	27	21	48
	Total	34	21	55

Sensitivity:	20.6 %
Specificity:	100.0 %
Predictive Value Positive:	100.0 %
Predictive Value Negative:	43.7 %
Concordance:	50.9 %

entry, calculation of descriptive statistics and development of contingency tables.[10]

3 RESULTS

Seventy-eight patients were identified as potential study subjects. Of the charts available for review, 55 contained a complete clinical evaluation and documented STB results. These 55 patients comprised the study subjects. The mean age at evaluation was 29.95 years (range, 18 to 72). Ten subjects were women (18.2%). Fifty-three subjects were designated aviation personnel or had been selected for aviation training. Of this group, 46 (87%) were officer/officer candidates and 7 (13%) were enlisted rates. One subject was a military dependent spouse. One subject was a retired Naval Flight Surgeon, who was part of a special longitudinal evaluation program being conducted at NAMI.

Thirty-four subjects (61.8%) were categorized as having physiologic syncope. The remaining 21 subjects (38.2%) had syncope attributed to another aeromedically significant diagnosis. No subjects were noted to have a discrepancy between referral and final diagnosis based on syncope category.

Out of all 55 subjects, only 7 (12.7%) had a positive STB. Analysis of the accuracy of the STB as a predictor of final diagnosis is shown in Table 2. The sensitivity was 20.6 %, specificity 100 %, predictive value positive 100 %, predictive value negative 43.7 %, and concordance 50.9 %.

Examination of the individual tests comprising the STB demonstrated that 5 subjects were positive on more than one individual test. Two subjects were positive on only one of the individual tests. The positive findings were distributed among three of the individual test items, with a total of 13 positive tests (Table 3). All 13 positive individual tests were positive based on subjective reports of reproduction of symptoms, i.e., near syncope. No prolonged asystole, dysrhythmia or frank syncope were produced. The two best performing individual tests were hyperventilation and maximal breath holding, each with a sensitivity of 14.7 %, specificity 100 %, predictive value positive 100 %, predictive value negative 42.0 %, and concordance 47.3 %. The two tests showed concordance with each other of 42.9 %. Bilateral ocular pressure showed concordance with hyperventilation of 71.4 % and with maximal breath holding of 14.2 %.

It should also be noted that three additional subjects were found to have subjective pre-syncope during hyperventilation that *was not* felt to reproduce the subject's symptoms. In all three cases, both the individual test and the overall STB were interpreted as negative. Only one of the three could be categorized as physiologic syncope. If we retrospectively reclassify these three subjects as having positive Syncope Test Batteries, the sensitivity becomes 23.5 %, specificity 90.5 %, predictive value positive 80 %, predictive value negative 42.2 %, and concordance 49.1 %.

Forty-six records had adequate documentation of the recommended aviation disposition, i.e., physically qualified or waiver recommended for aviation versus disqualification from aviation. Of the 7 subjects with a positive STB, only 1 of 5 (20 %) were recommended for return to aviation; no additional analysis of these limited data were appropriate. For all subjects with a negative STB, return to aviation duties was recommended for 15 of 23 (65.2 %) with physiologic, and 13 of 15 (72.2 %) with secondary syncope. Chi-square analysis showed $X^2 = 0.22$ (NS; $p > 0.05$).

4 DISCUSSION

From Table 2, the specificity and predictive value positive are both 100 %, which might be construed to indicate strong performance by the Syncope Test Battery. However, these two tests are relatively meaningless when looking at the whole of the data. The sensitivity is very low, meaning that the STB performed poorly in identifying patients with physiologic syncope. Further, the low predictive value negative indicates that a negative STB might inappropriately sway clinicians toward conducting a more extensive, invasive and expensive diagnostic workup than otherwise indicated by a well-performed history and physical examination. Lastly, the concordance of just over 50 % means that the STB has the same meaning as the fair toss of a coin.

The lack of usefulness of the STB is also supported by the analysis of the individual components. The test battery is made up of 13 individual tests. None of the orthostatic testing procedures were positive. The 13 positive tests found in seven subjects were scattered over three individual tests. Five subjects had multiple positive individual tests, but since each individual test focuses on a slightly different physiologic pathway for the production of syncope, the meaning of multiple positive tests is not clear. The only high concordance was between hyperventilation and bilateral ocular pressure, but the physiologic mechanisms governing these two tests are markedly different.

The STB also fails on another count. The results of the STB did not affect the final diagnosis for any subject. The final diagnostic category, physiologic or secondary, did not change from the referral diagnostic category, indicating that the STB had no impact on the diagnostic decision process.

There are several potential biases related to the retrospective nature of this study. Observer bias may be present, since the physicians and laboratory technicians conducting the STB were r˙ blinded to the referral diagnoses or the physician's initial clinical impressions. Thus, observer bias might make it more likely that the results be interpreted as positive if a physiologic syncope were suspected and negative if a secondary syncope were suspected. Subject reporting bias might be present, since subjects suspected of having physiologic syncope might be subtly cued to report test-elicited symptoms as a qualitative reproduction of their syncopal symptoms. Conversely, subjects suspected of secondary syncope might be cued to report symptoms as being qualitatively dissimilar, thereby producing a negative test. A related problem is the lack of rigorously specified protocols for conducting the individual tests. Knowledge of initial clinical impressions might result in subtle differences in administration of the individual tests. Tests might have been administered in ways more likely to produce syncope in subjects expected to have physiologic syncope than in other subjects. The three subjects with near-syncope but judged to have negative tests provides evidence that one or more of these biases may have been operative. Exactly how far these biases might have affected the final results is not knowable. The presence of these biases would only serve to falsely *increase* the likelihood that the STB would accurately distinguish between physiologic and secondary syncope. If we could accurately assess

Table 3. Positive NAMI Syncope Test Battery Results.

Individual Test Procedure	Number Positive
Orthostatic testing:	0
Horizontal	
Vertical	
Horizontal, then vertical	
Inverted head down	
Squatting-to-standing	
Provocative testing:	
Unilateral carotid massage	0
Bilateral ocular pressure	3
Breath holding, max inspiration	5
Valsalva maneuver	0
Hyperventilation	5
Cold pressor test	0
TOTAL	13

the presence and effects of these biases and control for them in the analysis, we would expect the true results of this study to be even more negative. Thus, making the assumption that these biases are present provides stronger support for our interpretation of the data, i.e., that the STB lacks usefulness.

There are other potential limitations to the study. The total study size was not large, always a limitation on the power of a study. Because of the relatively small study size, the influence of data unavailable due to missing or incomplete charts on the magnitude and direction of the study results is potentially significant and unpredictable. Also, it is possible that our search protocol did not identify all possible subjects who had been given the STB. However, it is noted that the yield of positive STB results was very low (12.7 %). A minimum of 20 additional subjects, *all* with physiologic syncope and *all* with positive STB results, would be needed to achieve a sensitivity of merely 50 % (and concordance of 64 %). It is highly unlikely that finding all previously unavailable data would produce such a dramatic change in the study results.

Review of the literature indicates that use of batteries of tests to elucidate the cause of syncope are not new. Dermksian and Lamb found that they could induce syncope in 17 of 55 syncopal aircrew subjects with a similar test battery.[11] However, in another study, the same authors using similar methods induced syncope in 21 of 50 "normal" subjects.[12] Newberry looked at orthostatic testing techniques and concluded that orthostatic factors were not related to factors affecting impaired consciousness in flight.[13] In addition to these studies, recent authors have emphatically decried the lack of any meaningful "gold standard" test by which to evaluate syncopal patients.[7,14]

How should the flight surgeon proceed when faced with an aviator who has had a syncopal episode? Fortunately, the general medical literature has a fairly well-established consensus approach to syncope, involving an algorithm based on a well-performed history and physical examination.[4,5,7,14] We have adapted this approach at NAMI to replace the STB (Figure 1).

This algorithmic approach is more informative when looking at the type of patient being evaluated. Age is going to be the most important patient characteristic in guiding diagnostic evaluation and aviation disposition. Several studies have looked at the "incidence" (actually lifetime incidence) of syncope in younger adult populations. Dermksian and Lamb found a 7 % incidence of true syncope in a survey of 5000 aviation personnel aged 17-62 (62 % response rate).[11] However, Lamb and Dermksian concluded that the incidence was closer to 15-25 % in a survey of 1980 USAF personnel aged 17-45 (> 98 % response rate).[15] Williams found a 21 % incidence in 891 college students,[16] and Murdoch found 32 % in South African military trainees.[17] These data contrast with a lower incidence of syncope (3-3.5%) found by Savage in a prospective analysis of an older population (30-62 years at the beginning of 26 years of follow up) in the Framingham population.[18] It is no surprise to note that the literature not only supports a difference in the incidence of syncope with age, but that the mechanisms of syncope are also different. Several studies have noted that "unexplained" syncope, vasovagal syncope and syncope secondary to psychiatric diagnoses are more common in the young adult population, and that other diagnoses related to aging such as

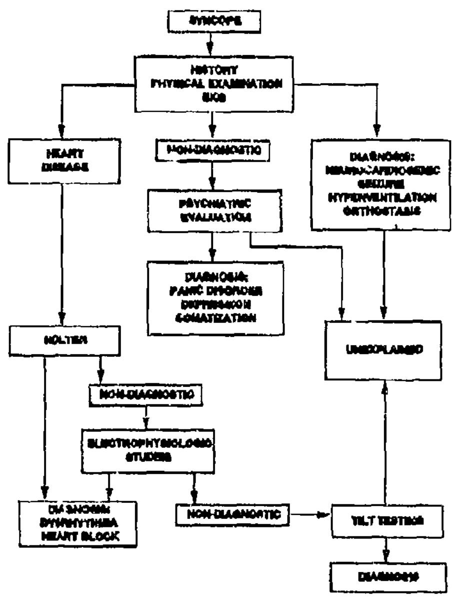

Figure 1. Syncope Evaluation Algorithm

coronary artery disease, cerebrovascular disease, autonomic neuropathies, etc., are related to the older population.[19-23]

"Unexplained" syncope often implies that insufficient history is available to label the episode as neurocardiogenic. With no firm diagnosis, this category of syncope defies prediction as to likelihood of recurrence and precludes development of treatment strategies. A diagnosis of neurocardiogenic syncope, comprising both vasovagal and vasodepressor types of syncope,[9] is more reassuring to the flight surgeon since the physiologic mechanisms of the Bezold-Jarisch reflex are well described.[9,14,24]

Neurocardiogenic syncope still presents a dilemma, since there is no diagnostic test to confirm such a diagnosis and the question remains as to whether or not a given aviator may be a "physiologic hyper-responder." Kapoor and Ross have both commented on the lack of a "gold standard" test by which to confirm the diagnosis or identify putative hyper-responders.[7,14] None of the commonly used orthostatic or vasovagal maneuvers that are known to produce syncope have defined population parameters or been correlated with the likelihood of producing syncope. Some recent studies have attempted to develop population parameters for some maneuvers, but as yet do not provide sufficient information for using these maneuvers to evaluate syncope in the general or aviation populations.[25-30] The technique of tilt table testing, both with and without isoproterenol infusion, has good theoretical relevance, has been used in aerospace medicine research, and has recently been in vogue as a tool for syncope evaluation.[31-35] In spite of data indicating the reliability of the tilt table test,[36-39] Kapoor has correctly pointed out and provided supporting evidence that the test is non-specific, and therefore currently must be viewed as having dubious validity.[40] It must be noted that the recent tilt table testing studies have used subjects with a wide age range, usually heavily weighted toward older subjects with additional medical problems. The real value of tilt table testing may not be known until it is evaluated within more rigorously and narrowly defined age- and diagnosis-referenced populations.

An interesting aspect of tilt table testing may be noted from studies looking more specifically at younger adult groups.[35-37] It appears that within that population, lower baseline pulse rate may be a predictor of tilt table-induced syncope. If so, then aerobic cardiovascular conditioning, resulting in lower vagally-mediated pulse, may predispose individuals toward increased syncopal response related to the Bezold-Jarisch reflex.[29] This may have important implications regarding both the evaluation of the well-conditioned younger aviator with syncope, and his/her susceptibility to G-LOC and strategies to combat G-LOC.[41-47]

The tilt table test currently is the best tool for the evaluation of an aviator with suspected neurocardiogenic syncope, but at best it can only be looked upon as adjunctive and possibly helpful. Aerospace medicine may have an important role in advancing the evaluation of tilt table testing based on the community's expertise in G-LOC and cardiovascular deconditioning in the microgravity environment. As an example, current tilt table testing methodology is standardized only on the horizontal angle to which the patient is raised. Our experience with G-LOC would indicate that the technique should control for the height of the heart-eye hydrostatic column, which even at 1-G might be an important factor differentiating shorter and taller syncopal aviators.[41,48]

The sequence of evaluation and resultant disposition of the syncopal aviator still largely defy hard and fast recommendations. Disposition will be related to prognosis, which for the aviator must include both the general likelihood of recurrence and the likelihood of recurrence in the flight environment. Obvious patient characteristics such as age gain importance as a consideration in the evaluation and disposition process. More extensive diagnostic evaluations focusing on the most likely underlying diagnoses based on age are defensible. In older adults, workups should focus on cardiovascular diseases and other diseases related to aging. In younger adults, neurocardiogenic syncope, psychiatric diagnoses, hypertrophic cardiomyopathy and aberrant cardiac conduction pathways must be considered.[22,23,49] With respect to general prognosis, the relationship of syncope to general mortality is related to the etiology of syncope, but is *unrelated to having had syncope*.[18-23] Therefore, disposition will largely depend upon the etiology of syncope and the risk of in flight syncope occurrence. Some conditions may be permanently disqualifying, but potentially curable diagnoses may allow the aviator to return to flying if the risk of recurrence during flight is

low. It is notable that the overall occurrence of sudden inflight incapacitation is relatively rare,[49 51] and Froom concluded that the causes are age related with the most important causative factors being hypertrophic cardiomyopathy in men under 35 years and coronary artery disease in men over 35 years. Syncope due to physiologic or unknown causes probably represents about one-third of the "loss of consciousness" subset of sudden inflight incapacitation events.[50-53] Neurocardiogenic and other physiologic syncopes in young adults in most cases may be so situationally dependent as to mitigate against the chance of recurrence in flight. However, another factor such as lack of flight experience may be a bigger hazard to the younger adult than the risk of recurrent physiologic syncope.[49]

Our data were too sparse to draw any meaningful conclusions regarding the influence of STB results on recommended aviation disposition. However, it is interesting to note that the X^2 analysis of the negative STB subjects showed no difference in the likelihood of being returned to aviation status for either the physiologic or secondary syncope groups, which ranged from 65.2 % to 72.2 %. Blackburn has reviewed the cases of 7 aviators evaluated by a Special Board of Flight Surgeons at NAMI in 1962, and found 4 of 7 (57 %) returned to a flight status.[54] Sundaram found that 50 of 88 (56.8 %) aviators evaluated for syncope at the USAF School of Aerospace Medicine in 1966-1967 were returned to flight duties.[51] More recent USAF data indicates that 112 of 124 (90.3 %) of syncopal aviators evaluated from 1985-1992 were returned to flight duties.[55]

In spite of several important technical advances (e.g., isoproterenol tilt table testing, electrophysiologic studies), the evaluation and disposition of the syncopal aviator has improved primarily through application of the principle: "work smarter, not harder." The general challenge will be to eliminate ineffective methodologies, and to develop reliable, population-based tools that are valid in identifying the likely cause of syncope and risk of recurrence. The accrued expertise in the aerospace medicine community in evaluating G-related loss of consciousness may provide valuable contributions to the general field of syncope research.

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THINK HEALTH NOT DISEASE

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Introduction

Clinical decisions in military aviation medicine must reflect operational requirements. *Aerospace medicine is special only because its practice serves a purpose, namely, to apply medical standards to an extremely demanding profession.* When nations choose to maintain military defence forces - one component of which being dedicated to exert air power — it is the occupational aspect with its preventive dimension that make aviation medicine a specialty.

The flight surgeon is, in fact, a mere guardian of public investments in aviators and airplanes.

Table 1. Defence expenditures in NATO Countries (% of Gross Domestic Product)

Country	1985	1988	1991	1992*
Belgium	3,0	3,0	2,5	2,0
Canada	2,2	2,2	2,0	2,0
Denmark	2,2	2,2	2,1	2,0
France	4,0	4,0	3,6	3,4
Germany	3,2	3,2	2,3	2,2
Greece	7,0	7,0	5,4	5,4
Italy	2,2	2,2	1,9	----
Luxembourg	1,1	1,1	1,2	1,2
Netherland	3,1	3,1	2,6	2,5
Norway	3,1	3,1	2,9	3,2
Portugal	3,2	3,2	3,1	2,9
Spain	2,4	2,4	1,3	1,7
Great Britain	5,2	5,2	4,2	3,9
Turkey	4,5	4,5	4,0	3,9
USA	6,5	6,5	5,1	5,5

* *Estimate*

The policies which determine public expenditures within various sectors of national pursuits — air power and military aviation medicine not excluded — are largely based on financial considerations and may be fully appreciated only when corresponding fiscal matters are taken into account.

State finances are fundamental to the philosophy of military medicine including health care for military aviators, regardless of the connection being recognized or not.

Although such an angle of attacking the problem of clinical decision making in aviation medicine might appear extraordinary, it is nevertheless basic to our discussions, so let's begin by taking a look at the economics involved.

Defence budgets are among the major public expenses in countries belonging to the NATO alliance ranging from approximately 1,5 to 5,5% of the GDP (Table 1). The trend is obvious when the defence budget is presented as fraction of the fiscal budget even if both may show growth. Taking my own country, Norway, as an example, the national defence budget is considerable, although the general tendency of western nations of reducing expenditures for defence purposes is evident (Table 2).

Table 2. Defence expenditures of Norway 1989-1994

Year	Fiscal budget	Defence budget	% share of Fiscal budget
1989	267.583	20.407	7,6 %
1990	296.796	21.893	7,4 %
1991	314.837	22.420	7,1 %
1992	335.630	23.156	6,9 %
1993	351.711	22.543	6,4 %
1994	357.405	22.962	6,4 %

* *Norwegian Crowns in millions.*

When distributing the Defence Budget between the three major services, it appears, however, that *the amount of money invested in air defence has not been curtailed over the past few years,* to the contrary, allocations to our Air Force have remained level (Table 3).

Obviously, with such an investment to protect, society demand both effectiveness of operations and flying safety. However, a requirement of simultaneous safety and effectiveness carries an essential discord due to the obvious hazards of military aviation. *This conflict constitute the raison d'être of military aviation medicine.*

Table 3. Allocation to armed forces by service (Norway)

	1992	1993	1994	Difference 93-94
Army	4,4	4,4	4,1	- 4,8%
Navy	2,4	2,4	2,4	- 1,5%
Air Force	3,1	3,0	3,0	+ 0,4%

* *Norwegian Crowns in billions*

The primary objective of military aviation medicine, therefore, is to contribute in an effort of producing personnel fit to complete air operations successfully with a minimum of losses.

Accepting that the principal aim of any air force is to attain combat readiness to such a level of excellence that operational leaders may confidently apply their units in battles fought in order to control air space, programmes aiming at military flying safety is just a means to an end of not unnecessarily loosing lives and expensive equipment, and, particularly not to appear a threat to third person's life and property - at least not in peace time.

Airborne weapon platforms are increasingly dominated by high technology, yet, largely human factor dependent. Consequently, selection of candidates suitable for military flying training, health management and retention of qualified aviators constitute major challenges to practioners of aviation medicine.

The marginal edge which separates success from failure when competing for air superiority may, in fact, be decided by those able to pick and to coach people with a potential to win in combat.

It follows that the health profile of air crew members is interesting only as far as it concerns their ability to perform well during unusually demanding actions in peace time as well as during warfare. For this reason most national air forces maintain expertise within the field of aviation medicine - applied psychology included - the purpose being two-fold: *firstly, to help build an effective fighting force by means of which to exert air power in hostile environments, secondly, to promote flying safety.*

Those suffering from unhealthy conditions of body or mind should not participate in air operations. Ilnesses, their treatment and the prognoses of recovery, ought to be left to physicians who see patients regularly, whereas continuous monitoring of air crew health is the responsibility of the flight surgeon. Moreover, any evaluation of fitnes for fight or abliilty to support the air struggle must reflect the operational tasks of the various aircraft in the inventory since the performance of the equipment flown to a large extent determines the human factor requirements of military aviation.

Such is the basic concept argued in this paper.

Purposeful Medical Decision-Making

When medical decisions are made for a certain purpose, evaluating air crew health, for instance, *the sources of information used* in order to arrive at conclusions need to be examined. Likewise, *the tools employed* in order to derive information must be reviewed with respect to applicability. Moreover, *the relevance of the information obtained* has to be carefully considered.

One essential difference between the practice of medicine when treating patients as opposed to occupational health care has to be expressed at this point :

as a rule, physicians see patients with histories of symptoms and signs, which, taken together, are recognized and investigated by *appropriate methods., i.e. procedures which are clinically indicated.* If the client to be seen is obviously healthy, administration of additional testing takes place without a clinical indication. The mere existence of sophisticated methods developed for diagnostic purposes does not validate their indiscriminate use. When healthy clients are, nevertheless, exposed to a battery of previously selected procedures in order to predict health, what would be the significance of such an approach?

With no history, no symptoms or signs, and, no normal material as a reference, physicians are at a loss and any conclusions arrived at may be seriously questioned.

Yet, this is exactly how aviation and space medicine is frequently being practiced when young candidates are selected as well as at routine medical examinations. Thus, there is an obvious need to justify resource management, methods used and clinical decisions made

These are unpleasant, but inescapable facts.

The Search for Medical Constants

It is almost a statement of the obvious to submit that *any scientific field of study which progress rapidly is characterized by a number of marvellous constants*, and, that the variables studied may be fairly well controlled, at least during experimental conditions. The swift

development of chemistry and physics, for instance, depends largely on the knowledge of exact figures which are either constants or may be accurately determined in time and space, by mass or wavelentghs, as energy content with states of energy to be calculated, and all of it described in the precise language of mathematics. These merits of expression are much to be envied by investigators of the life sciences who, in the absence of similarly sharp tools, are left to merely muddle through.

But medicine is not entirely without useful methods *provided they are properly applied to relevant problems that have been identified by questions which address key issues.* Certain central themes of health varies predictably with hereditary factors, medical history, age, sex, social frame of reference, etc. Moreover, in aviation medicine it is fair to assume that several testing procedures are carried out due to occupational justificationin accordance with preventive measures, thus, not necessarily being indicated by clinical considerations. Consequently, the problem that practioners of aviation medicine face, is to be aware to what extent knowledge derived using diagnostic procedures without a clinical indication may contribute to sound conclusions. *It is important, therefore, to keep in mind that the amount of relevant information thus obtained depends on the reason for and precision of inquiry.*

Two issues are more relevant than others when physicians make medical decisions without any clinically pertinent evidence. The first one is the *family medical history* because it gives an indication as to the genetic material carried by the person examined, the other is the *vital statistics of the society* in question since this is the main source for prediction of health based on age, sex, death rates, causes of death, and above all, how the panorama of disease processes expands during a lifetime These two factors are the *"constants of occupational medicine"* .

The first one, the family medical history, has to be penetrated in depth in order to predict future health in adolescence. Much information may be derived from anamneses alone. The second one, the vital statistics, as described by the Official Statistics of Norway is shown in Fig. 1.

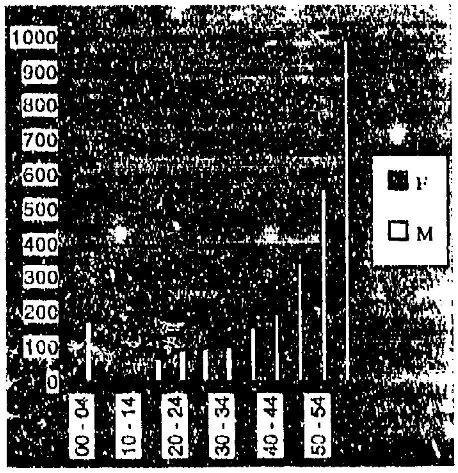

Fig 1. Death rates per 100.00 population in Norway 1991

it appears that having lived through the first 4 years of life, the possibility of an early death is very remote. Likewise, the death rate between 20 and 35 years of age is low and remains low through age 44. From this age on towards retirement age at 60 there is a rapid increase in the death rate per 100.000 population. A conspicuous difference between males and females is apparent already from age 15, this difference becoming increasingly marked as years go by - but for different reasons.

Selection

When selecting candidates for military flying training it is important to consider the time interval of effective air crew usage. It is convincingly shown (Fig.1) that the death rate for males between 20 and 40 years of age increases from about 100 to approximately 185 per 100.000, the corresponding numbers for females being 30 and 105, respectively. *From age 45 these rates increase conspicuously.* It follows that when selecting for aviators whose military flying carreer has either been terminated at age 40-45 by promotion into senior officer positions within the Air Force, or else, separation from the Air Force has taken place at the end of a contract period of 10-12 year, those selected upon

1. *reviewing the medical history of candidates in depth*
2. *physical examination emphasizing special senses*

3. *thorough psychological testing, and*

4. *specific investigations according to any loaded family history*

are not going to cause much trouble for flight surgeons. Moreover, at this stage there are *no clinical indications* for any further extensive laboratory procedures.

On the other hand, *there are several occupational risk factors* which could cause additional investigations to be performed at selection time. Candidates might — depending on national policies — be given an EKG, in some instances an exercise EKG, even an ECHO may be required. Furthermore, an EEG with provocations like hyperventilation and flicker stimulation is frequently added, likewise radiological investigations, blood lipid profile determinations, and for females gynecological screening test just to name a few procedures commonly performed. In the future one might consider testing for cancer-predisposition genes to be included. However, since the population of applicants probably constitutes an already highly selected healthy lot, the information derived from these advanced procedures could be almost negligible with the possible exception of those which are excellent predictors of disease according to familial characteristics.

The results obtained may be very valuable for future reference, of course, but even so,this does not increase their diagnostic value at selection time. Furthermore, a so-called "negative finding" is not significant at all, whereas pathological manifestations are, however few and far between. Worst of all are findings which would be obvious causes of suspicion among designated patients, but which cannot be referred for to a corresponding normal material for comparison in order to decide to what extent deviations from accepted standards are really pathological.

Examinations by means of *advanced and complicated methods developed for diagnostic purposes in real patients are likely to confuse rather than to enlight* unless the investigator knows exactly why the procedures are required in order to reveal conditions which might put the personnel at an occupational risk, and, how the evidence should be interpreted and used in an operational perspective.

Management and Retention

With respect to health management and retention the over-all picture of vital statistics for Norway is already presented in Fig.1. However, in order to illustrate important aspects of public health, it is necessary to break data down in order to identify major causes of death. The results as presented in Figs. 2 and 3 show cardiovascular diseases and malignant neoplasms to be the main killers in both sexes and at all age groups above 40. The differences between the sexes are also apparent. Likewise, violent deaths is shown to be a sizable problem (Table 4).

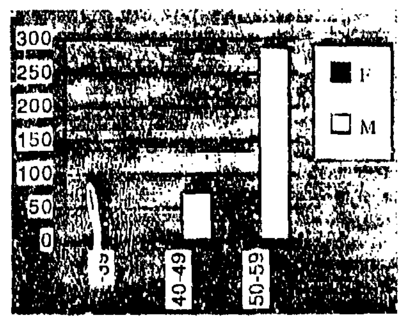

Fig 2. Sex and age specific death rates Norway 1991 due to cardio-vascular diseases (Deaths per 100 000 population).

In many cases untimely morbidity and mortality are preventable, particularly if a determined effort of intervention is made early on. In fact, the one thing that flight surgeons are able to do successfully is to *think health, not disease* from the day of selection, introducing lifestyle measures and information aimed at delaying any disease process. Moreover, those mentally and physically

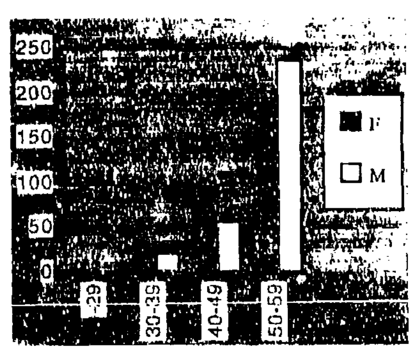

Fig 3. Sex and age specific death rates Norway 1991 due to malignant neoplasms (deaths per 100 000 population)

fit are less vulnerable to disease, and, they are less likely to exhibit severe sequalae after illness.

Table 4. Sex and age specific cases of violent death (Norway, 1991)

Cause	Total	0 - 14 years		15 years and above	
		M	F	M	F
Accidents	1780	30	24	1003	723
Injuries *	23	-	-	16	7
Suicides	675	4	1	495	175
Homicides	66	2	3	44	17

* *Undetermined circumstances*

Therefore, determined intervention is real health management, besides, it greatly helps medical decision-making because of an easier recovery and a more predictable prognosis. *In fact, the period of time between 20 and 45 constitute a crucial period of age during which the lifestyle is likely to influence the ageing process.* Furthermore, in our experience, personnel whose occupational success depends on physical and mental fitness respond well to suitable training programmes. These are reasons why flight surgeons should concentrate on health, not disease. Retention is quite another matter since we are really dealing with someone who has been ill already. The latter may be treated by any qualified physician, but for the aviators future career the result of treatment is to be evaluated by specialists in aviation medicine. Again, practitioners of military aviation medicine should not indulge in the treatment of patients, but rather evaluate recovery. It is far more important for the flight surgeon to carefully consider health than to be over-cautious about disease.

Summary

At selection time many important medical decisions are made, most of them relying on simple clinical methods such as preliminary case history and physical examination. Information obtained using sophisticated laboratory methods may give crucial information when results are evaluated against occupational hazards, but it is important to keep in mind that such procedures are not clinically indicated.

Health management of those successfully trained is not performed towards a background of disease but to the contrary, in order to promote health.

Retention of those treated for illness is a decision of fitness to fly after evaluation of treatment. Clinicians may be satisfied with the treatment of a patient, flight surgeons may or may not be happy with the result considering the occupational hazards of military aviation.

It follows that selection, health management and retention of aviators are in principle considerations of health not of disease.

Examinations performed on asymptomatic military aviators using diagnostic high technology instrumentation may not contribute essentially to medical decision making.

NEUROPSYCHOPHYSIOLOGIC SEQUELAE OF MILD HEAD INJURY

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SUMMARY

Psychologic or neuropsychologic consequences of severe closed head injury have received much attention in both clinical and experimental studies. Nevertheless, it has been clearly established that even mild closed head-injured patients may develop psychologic or even psychiatric sequelae of clinical relevance, including poor social adjustment as well as cognitive impairment. Symptoms such as dizziness, fatigue, irritability, headaches, insomnia, anxiety, and amnesia are also frequently reported, these being usually the major features of post-concussion syndrome.
Cognitive impairment is responsible of attention and concentration capability disorders, with consequent difficulty in retrieving acquired information and performing usual tasks.
Full or satisfactory recovery from such symptoms is normally achieved in few months, with persistence in a minority of cases with distinct risk factors (age, gender, multiple trauma, history of previous head injuries).
Such manifestations of head trauma are satisfactorily detected and followed up by means of specific neuropsychologic tests in several studies, while CT-scan, according to many Authors, fails to provide but scarce prognostic reliability. The role of neurophysiology is controversial, although opinions are that it should be referred to in selected cases and in a multidisciplinary approach.
Finally, an interesting and significant correspondence of neuropsychologic tests, behavioural data and MRI or SPECT findings casts a new light on both clinical and research aspects of the question.
Making a decision whether returning a head-injured pilot to flight activity or not certainly constitutes an additional problem for the risk of epilepsy and of other neurological or neurosurgical complications is to be considered of primary importance even for mild head trauma (which accounts 75% or more of the total, with an annual incidence of about 150 per 100,000 population).
Neuropsychologic sequelae themselves do require a restriction from flying duties for months or years. It is advisable to await normalization of neuropsychologic and neurophysiologic parameters, in absence of neuroimaging (i.e. MRI) signs, before returning the patient to flight activity. Neurophysiology (EEG, evoked potentials) provides cost-effective, sensible and reproducible means for diagnosis and follow-up and its value could be boosted by the implantation of an individual neurophysiological database for all the flying personnel

1. INTRODUCTION

Mild head trauma is a main public health concern in Europe and Northern America. Although data on annual incidence vary according to the Authors it is postulated that at least 130 to 150 mild head injuries (MHI) per 100,000 population occur every year[1,2], with a strong prevalence in males and in young individuals. MHI approximately account for 75% to 82% of all head injuries.
Although the severe head trauma has always been identified as an important source of motor and psychological disabilities, the sequelae of mild head injury have been underestimated. This is largely due to the scarce attention that syndromes commonly labelled as "compensation" or "litigation" neuroses have received in the literature until few years ago.
It is now clear that anxiety, insomnia, irritability, dizziness, fatigue, as well as a cognitive impairment can develop as a consequence of a MHI (Post-Concussion Syndrome). It seems that those in dangerous occupations are at higher risk for such a syndrome[3]. Usually these manifestations tend to resolve within 3 to 6 months from the trauma, with a persistence in a minority of cases.

TABLE I

Major risk factors for MHI sequelae

- Age > 40
- Female gender
- Alcohol abuse
- Prior head trauma
- Multiple trauma

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generally characterized by distinct risk factors: age over 40, female gender, alcohol abuse, prior head injury and multiple trauma[2] *(Table 1)*. Difficulties in assessing the exact risk for sequelae of any kind following a MHI arise from the lack of a precise agreement among the Authors on when a head trauma should be classified as mild. The classification criteria for MHI generally include a closed-head injury (CHI) with an initial period of unconsciousness lasting less than 20 to 30 minutes according to different Authors, no deterioration from an admission Glasgow Coma Scale (GCS) score[4] of 13 to 15, no Computed Tomography (CT) evidence of an intracranial mass lesion (with the exception of a punctate hemorrhage), and no intracranial complications such as hypoxia (PaO_2<60 mm Hg) or shock (systolic blood pressure < 90 mm Hg)[5,6] *(Table 2)*

TABLE 2

Classification criteria for MHI

- LOC duration < 30 min

- GCS score (13-15)

- No mass lesion on CT scan (except: punctate hemorrhage)

- No hypoxia ($Pa\,O_2$ < 60 mmHg)

- No shock (systolic blood pressure < 90 mmHg)

Fig. 1 Composite drawing of the areas most frequently involved in MHI (from ref. 14, modified)

The exact site of brain damage in MHI is still matter of discussion (fig. 1). Many different mechanisms have been postulated to explain gross or subtle deficits that can be detected after a MHI. The shear-strain model may account for many of neurologic and behavioural aspects of MHI[7]. This model suggests that acceleration-deceleration injuries produce axonal tearing and neural degeneration in ascending or descending tracts of the brain stem[8] or in the white matter of brain hemispheres. Unconsciousness is hypothesized to be generated by a rapid movement of the brain mass within the skull, with a stretching and tearing of fibers and impact damage. The finding of microscopic lesions in the medulla and pons, primarily in the area of rostral pyramids, seems to support this hypothesis. Brain stem axonal degeneration was observed in monkeys with acceleration-deceleration injuries, analogous to MHI in humans[9]. Oppenheimer found similar lesions upon postmortem examination of people who had sustained MHI[10]. The pathological findings have been differently associated with neuropsychologic and neurophysiological aspects of MHI.

Neuropsychologic sequelae as well as neurophysiology and neuroimaging of MHI will be examined in the following sections. It must be anticipated that reference will be often made to moderate or severe head injuries to point out the specific sensitivity and reliability of different diagnostic approaches.

2 NEUROPSYCHOLOGIC SEQUELAE

Some aspects of the numerous neuropsychologic sequelae of MHI must be stressed due to their relevance for aircrew efficiency and flight safety.

MEMORY

Memory impairment is a common experience for head-injured people. Difficulties encoding, storing and retrieving new information can persist long after a satisfactory recovery of general intellectual functioning. Incidence of permanent verbal and visual memory impairment varies from 25% to 48% in moderately or severely head injured patients[11,12]. Severe memory deficits can be found despite Wechsler Verbal and Performance Intelligence Quotients[13] within the normal range[12].

Characteristically mildly head-injured patients show little deficits in immediate recall, while delayed memory after a period of distraction is significantly impaired as compared to controls[15,16,17]. One of the most sensitive test to detect such impairment is the Verbal Selective Reminding (VSR) procedure[18]. This test is frequently employed to evaluate long term verbal memory, an ability that depends on the integrity of temporal lobes. It consists of a 12-word list administered over 12 trials. On each trial the examiner presents only those words which the patient failed to recall on the preceding trial. A delayed recall trial is given 30 minutes after completion of the 12 trials.

Long term memory for nonverbal information can be assessed through an analogue of the VSR test; the patient is asked to recall a spatial configuration of eight marbles on a board consisting of 16 locations, with a delayed recall trial given 30 minutes after completion of the 12 trials.

In short-term follow-up (1 to 3 months) the head-injured group constantly exhibited defective baseline performance on all such tests but the percentage of patients performing worse than control groups was greatest for long-term memory procedures.

Memory impairment as a sequela of MHI seems to be somehow linked to post-traumatic amnesia, a period during which the patient is unable to store or to retrieve day-to-day information, including orientation to time and space as well as events immediately preceding or following trauma (respectively retrograde and anterograde amnesia). Post-traumatic amnesia duration of more than 2 weeks is prognostic of prolonged or permanent memory deficits[11,19]. Generally temporal or frontotemporal lesions are considered the most dangerous for a prolonged memory impairment[20]. Duration and severity of memory impairment following moderate or severe head injuries are correlated to GCS score within 24 hours of injury, duration of impaired consciousness and oculocephalic/oculovestibular responses[21,22]. Non-reactive pupils during the acute state of injury has been

also associated with an increased incidence of memory deficits[12,15,21,22]

ATTENTION
Mental slowness and deficits in focusing or maintaining attention are related to each other and both are frequent complaints of head injured patients. Once again these patients may fall in the average range of intelligence and simultaneously perform consistently below the level of non injured controls. As the demand of a task increases mental slowness becomes more evident, e.g. paying attention to three dimensions of a stimulus[23]. A divided attention deficit (defined as slowness in consciously controlled information processing, an inability to process multiple bits of information rapidly and easily) was found by Stuss et al.[23]. This study confirmed that tasks of divided attention are very sensitive to the effects of injury, even in mildly concussed or apparently recovered patients[24,25]. A focused attention deficit (defined as the inability to suppress an automatic response when conflicting response is demanded, or as the unnecessary processing of redundant information) was also found by the Authors. The patients seemed to be less able than the control group to ignore redundant information. The Authors suggest that head injured patients can rise to meet the demands of a focused attention task but are inconsistent in maintaining an optimal level of performance.
The PASAT test (Paced Auditory Serial Addition Task)[26] is sensitive to attentional deficits for all severity injuries and is a good marker of recovery in MHI. In this test the patient pays attention to a list of numbers presented on tape-recorder. He is required to add each figure to the one immediately preceding, with the speed of presentation of the digits progressively increasing (e.g. he hears "5" and "3" and answers "8"; then he hears "6" and answers "9") Impairment on this task has been demonstrated up to 5 years post-trauma [27,28]. Gronwall and Wrightson suggested that MHI significantly reduces the capacity to process information rapidly and that deficit in information storage and retrieval are exacerbated by successive injury [29,30]. Reaction time tasks are usually altered in head injured patients, especially if different or multiple stimuli are presented at the same time[23,31,32,33] Driving performance is an excellent example of such impairment and will be discussed later.
The mechanisms hypothesized for this kind of damage are either a degeneration of the white matter or a diffuse axonal injury.

VISUOMOTOR ABILITY
Van Zomeren and Deelman[33] performed a 2-year follow-up study on a group of 57 CHI young male patients. The group was divided into three subgroups according to the severity of trauma (mild, moderate, or severe). These patients were tested for reaction time on both simple and four choice visual reaction task. The apparatus was made of a panel with a vertical row of four white lights, placed next to four black push-buttons (in the simple reaction test only one light and one button were visible). Patients were asked to push the button next to the presented stimulus as quickly as possible. The effect of groups was found to be significant; the overall reaction times in each of the groups were 386, 405, and 465 ms (milliseconds). The interaction of groups and complexity was also significant, as the difference of reaction times between simple and choice reaction tasks was 198, 228, and 269 ms respectively in mildly, moderately, and severely head injured patients. During the scheduled follow-up, reaction time on choice reaction task decreased more rapidly for the MHI subgroup as compared to the moderate head injury subgroup, and for this subgroup as compared to the severe. Reaction time curve on simple reaction task showed a similar decrease but at faster pace, this increasing the gap on the complexity of tasks between the subgroups. As the results of this test suggested, reaction time tasks can discriminate between grades of severity of head injury and complexity of task enhances the sensitiveness of the test. Recovery curves for the mild head injured subgroup approached the asymptote in few months after trauma.
In a driving ability test, performed 2 years post-injury on severe injured patients, a significant difference was found from controls in terms of shifting, braking, dodging cones on a slalom[34]. Similar results were achieved by Van Zomeren et al. [35] on patients who sustained severe head injuries several years earlier. These patients were asked to drive an instrumented car that recorded lateral position control on a highway track. They matched by age and driving experience to a control group. The former performed worse in the driving tasks, as well as in a neuropsychologic test battery, despite the long intervals since their injuries. Although these data refer to severe head injuries, visuomotor problem solving skills seem to be highly correlated with cognitive functioning after a MHI.

PROBLEM SOLVING
Concept formation and flexibility in problem solving is generally considered a measure of orbito-frontal and temporal lobes functioning. Diffuse white matter damage has also been hypothesized to interfere with frontal connections and subcortical structures[17]. Wisconsin[36] and Modified[37] Card Sorting Tests (MCST) can be employed to evaluate problem solving capability. These procedures use cards that vary along the three dimensions of colour, form, and number; the patient is asked to determine which sorting rule is correct based upon the feedback given by the examiner after each trial. The sorting rule changes after a several correct sorts. Head injured persons tend to make perseveration errors (staying with a previously reinforced rule despite negative feedback) and generation of few hypotheses[38]. The MCST is generally employed along with the test of verbal fluency[39,40], which is thought to explore left frontal lobe functioning, and the test of design fluency[41], which is thought to explore right frontal lobe functioning. The former consists in generating words beginning with a designated letter within a time limit of 60 seconds, while the latter consists in inventing designs that can not be named, making them different from the original designs, under timed conditions.

3 NEUROIMAGING OF MHI

Computed tomography (CT) scans are routinarily performed in emergency departments, trauma centers or neurosurgical units. CT is of great value in detecting lesions requiring neurosurgical intervention, such as epidural or subdural hematomas or intraparenchymal hemorrhages. Nevertheless it fails to provide useful information about primary cerebral damage. Primary intraparenchymal lesions are normally seen only in

severely injured patients. Magnetic resonance imaging (MRI) sensitivity in detecting primary brain damage is at least twice as high as CT [41]. Jenkins et al.[42] studied 50 patients with closed head injury. Of these patients 4 did not lose consciousness at all, 4 were fully conscious by the time of admission to hospital (GCS=15), 14 had a GCS score <8, and 28 a GCS score between 9 and 14. Forty-six patients had an abnormality shown by MRI (lesions involving the cortex in 44 - in isolation in 14 and with other lesions within the parenchyma of the cerebral hemispheres in 30). CT scans detected abnormalities only in 25 cases (23 had cortical contusion, 23 a lesion in the subcortical white matter, 3 had deep lesions). MRI findings seemed to correlate pretty well with the level of consciousness. All 4 patients without loss of consciousness had a cortical contusion but no deeper lesions. Eight patients lost consciousness for less than 5 minutes; 6 had cortical lesions and 2 had intracerebral lesions. Of 31 patients who had an impairment of consciousness lasting more than 5 minutes 29 had cortical lesions and 24 had subcortical or deeper parenchymal lesions. It is interesting to notice that all 8 patients who recovered full consciousness had cortical lesions, but no lesion in the white matter or basal ganglia.
Levin et al. studied 20 patients with mild or moderate (GCS between 9 and 12 irrespective of CT findings) head trauma[5]; 17 had lesion that were visualized by MRI but were undetected by CT, including 8 patients in whom CT showed no evidence of an intracranial lesion and nine in whom MRI revealed lesions in addition to those found on CT. A disparity of CT and MRI findings about the size of intracranial lesions was also described. In this study Levin et al. investigated the relationship between MRI and neurobehavioural sequelae of head trauma. Frontal lobe lesions were differentially related to the impoverished generation of novel responses and to increased perseverative errors, and temporal lobe lesions were associated with disproportionate impairment of long-term memory. Reduced verbal fluency was common in patients with left frontal lobe lesions. Parenchymal lesions resolved within 1 to 3 months and this was paralleled by improved performance on neuropsychological test and resumption of normal activities.
Few studies have investigated the correlation between regional cerebral blood flow and neuropsychological findings of head injuries[13,41]. Oder et al. performed a Single Photon Emission Computerized Tomography (SPECT) on severely head injured patients. The values of regional blood flow were correlated to behavioural and psychosocial evaluation of the same patients. A significant correlation was found between low regional cerebral blood flow in frontal lobes and disinhibitive behaviour. Higher left cerebral hemispheric flow values were associated with worse social role functioning, maybe due to the patients' deeper awareness of their residual deficits and problems in social adjustment, and consequent withdrawal from social interactions as the easiest coping strategy available. Low flow values of right brain regions were associated with aggressive behaviour.

4 NEUROPHYSIOLOGY OF MHI

The neurophysiological approach to the head-injured subject mainly include electroencephalographic (EEG) and evoked potentials (EPs) examinations. For instance, it was shown that the EEG pattern correlates well with cerebral blood flow (CBF) and metabolism (CMR) under normal physiological conditions[45,46], even if in the acute phase after brain injury there is often hyperemia in spite of reduced cerebral function - and slowing of the EEG -, i.e. an uncoupling[2,47]. In the later chronic phase, the coupling between function and blood flow is restored. Three mainly neurophysiological approach will be considered: conventional EEG, quantified EEG (QEEG) and EPs.

CONVENTIONAL EEG

Conventional EEG monitoring in the acute state provides valuable information about changes in the level of consciousness, with certain typical features that are related to the course and to the outcome of head injury[48]. Irrespective of the pathophysiological mechanism(s) underlying the neuronal damage in head injury, EEG abnormalities can occur for lesions both of the brain and of its protective coverings, and may be due to both diffuse and focal changes which may vary from one moment to another. They depend on the time from the onset of injury, its evolution, the appearance of complications, and above all on the patient's level of consciousness. The following are some conventional (visual) EEG features mostly occurring in severe head injury[49].
Generalized abnormalities: they include, in order of decreasing severity, electrical silence (brain death); diffuse depression with bursts of slow waves; generalized slowing (with loss of clear spatial distribution of rhythms); slowing of the alpha rhythm (alpha coma with uniform 8 c/sec rhythm); generalized fast activity; diffuse spontaneous spike-and-wave activity. The last one occurs only in children and if it appears after the age of 15 years a past or family history of epilepsy should be investigated.
Localized abnormalities: focal reduction (amplitude) of alpha rhythm; localized flattening; localized change of alpha frequency; localized slowing (theta and delta waves).
So-called "irritative" abnormalities: isolated spikes; electrographic seizure activity (primarily or secondarily generalized, with marked asymmetry and focal depression or slow waves).

Tysvaer[50] has recently studied MHI examining active football (soccer) players and former players of the Norwegian national team with conventional EEG evaluations, finding a higher incidence of abnormalities in both groups than in controls.

Post-traumatic epilepsy (PTE)

PTE is one of the most common and serious late complication of head trauma.
In different studies the rate of PTE among the several types of epilepsy ranges from 4,3%[51] to 23%[52]. Incidence in males IS at list twice as high as in females. War, home, sport, industrial, and mainly traffic accidents are the most frequent causes of head trauma and PTE.
Head injuries have complex mechanisms. The damage to the brain tissue may be much more widespread with respect to what the clinical, EEG and CT scan findings may suggest.
It is very important to underline the difference between the terms epilepsy and seizure and, therefore, post-traumatic seizures (PTS) and PTE. In fact, epilepsy is a chronic brain disorder characterized by recurrent seizures,

whereas a seizure results from an excessive neuronal discharge. Any single epileptic seizure after head injuries is not PTE but either an immediate, early, or late PTS. Chronically repeated seizures may be considered PTE. Although there is an overlap between the three types of PTS, they have different characteristics in terms of onset after head trauma, triggering factors, pathophysiological mechanisms, age dependency, clinical course, responsiveness to antiepileptic drugs, and above all they imply different risk factor for the development of PTE.

Immediate PTS

The latency from trauma of immediate PTS ranges from seconds to max. 5 min., even if some Authors have considered higher limits up to 60 min. These seizures mostly occur from 1 to 5 years of age. The incidence varies according to the upper limit of latency. The clinical feature is often that of generalized convulsion. They have no effects on PTE development.

Early PTS

They occur from 5 min to 1 week after the trauma. 25-30% of early seizures occur during the first hour after head injury[53,54]. They are most frequently observed during the first year of life. They are present in the past history of 25-33% of the PTE patients, with a higher risk for those over 16 years of age and 2/3-3/4 of early PTS are followed by PTE[55,56,57,58,59,60].

Late PTS

They occur after the first week post-trauma 95% of the cases occur within 3 years after the trauma.

The incidence of head trauma among patients with epilepsy is 2-3 times as higher as in general population. There is a good correlation between the severity of head trauma and the onset of seizures. Closed MHI causes seizures in 0.1% of subjects after 1 year and 0.6% after 5 years whereas severe head injury implies seizures in 7.1% after 1 year and 11.5% after 5 years[61].

The loss of consciousness is the most reliable index of brain damage. Different levels of consciousness after head trauma were correlated to the incidence of early seizures during war time head injuries: alert soldiers, soldiers responding only to commands, and soldiers responding only to painful stimuli had early seizures proportionally ranging from 2.8% to 7.5%[14]. The duration of loss of consciousness is also a predictor of the occurrence of seizures.

Another important aspect to take into account is the age of occurrence of the trauma. In fact the upper limit of latency of seizures onset is higher for children than for adults[62].

In conclusion, the risk of developing PTE depends on the nature of head injury, the duration of loss of consciousness and of amnesia, and is much more higher in severe penetrating trauma (50% of PTE within the first year) respect to blunt trauma (5% of PTE within the first year).

QEEG

The constellation of postconcussion symptoms typically reaches its peak in the weeks following the injury and sometimes persists for 6-12 months. However, there is no agreement in the studies about the resolution of these symptoms after this period, mostly because of inconsistencies and difficulties in the detection and quantification of neurological damage, a problem rising even when evaluating EEG only with a visual approach. The development of topographic EEG methods with computer frequency analysis, i.e. QEEG, provided the possibility of a more detailed regional analysis of EEG abnormalities. In particular power spectral analysis of coherence and phase of the EEG has been shown to be an useful technique for the diagnosis and prognosis of head-injured patients. These sophisticated procedures, involving computational analysis of the neurophysiological signal, were recently demonstrated to be an effective tool in reflecting the topographic functional inhomogeneities present in mild head trauma[63,64,65,66] and the best predictors of outcome at 1 year following severe, moderate and mild closed head injuries[67,68].

The results of a recent study[69] demonstrated that EEG coherence and phase discriminated patients admitted to an emergency service with mild head trauma from age-matched normals with high accuracy (> 90%) at various time following injury. A specific electrophysiological pattern was present shortly after injury and persisted in a relatively stable form for an extended period of time, reflecting a difference in the neurophysiological organisation of the cerebral cortex in normal versus mild head-injured individuals. Three classes of electrophysiological features were found in this study: class I was represented by local frontal, temporal and central-parietal abnormalities in EEG coherence and/or phase which involved short interelectrode distance (e.g., approximately 7 cm); class II was represented by long interelectrode distance (e.g., 21 cm), intrahemispheric power differences (i.e., frontal-posterior amplitude differences); class III was represented by diminished alpha activity in posterior cortical regions (i.e., occipital, parietal and posterior temporal).

These Authors considered these 3 classes to be consistent with the mechanics of cerebral trauma which involves shear-strain and rotational forces that damage white matter, and localized contusion of the grey matter: the localized frontal EEG coherence and phase abnormalities are consistent with localized contusions and axonal injury to frontal region, the posterior cortical diminished alpha activity is consistent with "coup-contra-coup" damage to posterior regions and reduced cortical excitability in general, while the diminution of the intrahemispheric power differences may reflect decreased functional differentiation between anterior and posterior cortical regions. When the patterns of these discriminating EEG variables were considered as a whole, the most consistent interpretation was that the consequences of a mild head injury are the development of a new neurophysiological stable state characterized by a combination of the effects of localized contusion and a diminution of the total magnitude of functional cerebral differentiation and, thus, reduced information processing capacity. Mild head trauma patients appear to exhibit 2 components of cerebral damage: (1) localized dysfunctions specific to areas of maximal injury, and (2) a global or generalized state of reduced information processing capacity.

The strength and temporal stability of the EEG pattern were therefore thought to be indicative of a new equilibrium state of the cerebral cortex which allows an individual to cope and adapt to the environment even though the nervous system has suffered mechanical damage. An important aspect of this hypothesized dynamical "new equilibrium" is that it appears to arise

shortly after injury and persists with only slight decline in magnitude over time. The functional significance of the relatively permanent and stable EEG discriminant pattern might be the degree to which it allows individuals to utilise available cerebral resources. Moreover, the neuropsychological deficits observed in mild head-injured patients are not inconsistent with these QEEG results.
In another investigation measures of conventional EEG and QEEG, together with other diagnostic procedures, were utilized to study patients with chronic traumatic frontal lesions[70]. A high correlation was found between lesion volume (measured using MR, rCBF, SPECT), but not injury severity as measured by consciousness parameters, and modal frequency in the EEG. These findings seem to be contradictory, but the Authors hypothesized that measuring injury severity in terms of duration of impaired consciousness, a common index in studies on closed head injury, might be misleading in cases of penetrating or open head injury, in which loss of consciousness is less common. In these cases, both lesion volume and indices of impaired consciousness must be considered when determining the injury severity. Moreover the modal frequency, and to some extent theta power, correlated with neuropsychological test results and general outcome ratings.

EPs
Nowadays EPs provide cost-effective, reproducible, sensitive, and quantitative extension of the clinical neurological examination.

Sensory evoked potentials
Somatosensory evoked potentials (SEPs) recorded from the scalp over the parietal regions have been widely used in the management and prognostic assessment of patients with severe head injury (SHI)[71,72,73,74,75,76,77,78,79].
SEPs allow the calculation of the "central somatosensory conduction time" subtracting the peak latency of the cervical potential from that of the initial cortical response (N13-N20). In subjects with post traumatic coma this measure is a reliable indication of outcome and an assessment of brain damage[80]. Their resistance to sedative drugs and the relatively long pathway, including brain-stem and thalamo-cortical structures, have made SEPs a method of choice in SHI, in which brain-stem damage is frequent and relaxation and sedation often render clinical and electroencephalographic evaluation difficult. A quite common feature in the literature on SEPs in head trauma is the possibility in some patients of a good recovery of clinical symptoms with still abnormal EPs. Somatosensory evoked potentials were found abnormal in a high percentage of patients with severe head trauma 94,8%[81].
Most studies agree that the presence or absence of the parietal component of a SEP over one or both hemispheres represents the most important single predictive outcome parameter.
Some Authors have recently found an interesting dissociation of frontal and parietal components of SEPs in SHI[82]. In particular, their results show that on the basis of the normal parietal SEPs, the prognosis would have been estimated far too favourably, whereas the strongly pathological frontal SEPs reflected the outcome more accurately. Moreover, in the absence of parietal responses the preservation of frontal SEP components allows for a better outcome estimate than would be suspected from evaluating parietal responses alone. The Authors concluded that both frontal and parietal components as well as both latency and amplitude of the frontal component must be considered to obtain the best prognostic evaluation in SHI patients.
In some studies SEPs appeared to be more reliable than auditory responses in predicting outcome in subject in coma due to severe head trauma[83,84,85].

Abnormal brain-stem auditory evoked potentials (BAEPs) are predictive of an unfavourable outcome in severe head trauma.
In MHI BAEPs investigated at the usual stimulus rate of 10/s did not show significant interpeak latency differences. Increasing the stimulus rate (55/s) it was possible to obtain a significant but reversible delay in the central conduction time[86].
Changes in the morphology and in the latency of the waves I, III and V (significantly prolonged) were found in 51% of children immediately after head trauma. The regression of the traumatically- conditioned BAEPs changes began during the first days after trauma and finished within 6 months in half of the children[87].
The reliability of BAEPs (and also middle latency responses) in predicting the outcome of severe head injury appears to be greater than other usually considered clinical and instrumental data (age, GCS, CT scan, EEG)[88].
The most commonly used parameters to define abnormal BAEPs are an increase in the wave I-V interval or the loss of any of the three most stable components (I, III, V).

The pattern-shift visual evoked potentials (VEPs) -which use a structured stimulus- were found abnormal in MHI subjects just in little percentage (11%) while the changes were more represented in moderate and severe head injury (39%)[89].

Examining multimodality evoked potentials (MMEPs) it has been evident that the integrity or complexity of the EPs waveforms appear to be the best indicators of the reversibility of injury of the CNS[90,91,92].
Pierzchala et al.[93] in a prospective study showed that brain concussion (MHI) causes a different pattern of MMEPs abnormalities respect to brain contusion. In concussion the highest frequency of abnormality occurs during the first month after the trauma and the lowest incidence after 6-8 months after the trauma. In contusion there is a highest incidence of abnormalities during the first month and even an increase at the end of the follow-up period.

Motor evoked potentials (MEPs)
MEPs are generated by stimulation of the motor cortex through the intact skull. Although MEPs provide objective, numerical data relating to the functioning of central motor pathways, Ebner and Zentner[94] showed that SEPs are superior to MEPs as prognostic indicator of coma in severe closed head trauma.

Cognitive evoked potentials (Event-related evoked potentials, ERPs)
Rugg et al.[95] suggested that ERPs might be an useful mean to study the effects of brain injury because:
- ERPs are sensitive to a number of important cognitive variables;
- they give a relatively direct real-time record of some of the neural events correlated with test of performance;

- the scalp distribution of ERP's abnormalities may allow the formulation of hypotheses of abnormally functioning regions of the brain.
In severe head injury Olbrich et al.[96] found the P300 a sensitive indicator of cognitive impairment that correlated well with the findings on neuropsychological tests. The P300 latency abnormalities persisted while cognitive abnormalities returned to normality, suggesting residual cerebral dysfunction in severe head trauma. Furthermore, in severe brain injury it is possible to elicit a P300-like response also in patient in a vegetative state exposed to passive P300, with P300 amplitude larger during a bimodal stimulus[97]. Pratap-Chand et al.[98] carried out a follow-up study in a group of subject of different age and sex with MHI using a classical auditory oddball paradigm. They found significant abnormality (with respect to a matched control group) in P300 latency and amplitude (on Cz-M1+M2) in 35% of the patients in the post-concussive period (within 4 days from head trauma). No correlation was found with GCS (13-15), duration of loss of consciousness (max. 30 min), post-traumatic amnesia (max. 60 min), and post-concussional syndrome. The most interesting result - for the aeromedical decision making - is that the abnormalities improved in a period of about 30 days. These findings are in agreement with those of Gentilini et al.[99] who found that cognitive impairment did not persist one month after MHI. Wirsén et al[24] in the same above mentioned study did not find abnormal P300 latency, whereas regional (Fz and Cz) P300 amplitude was smaller in patients than in controls. According to the current hypotheses about P300 generators and significance, these findings were explained in terms of an impaired cognitive processing of the stimuli due to the frontal lobes damage. It seems that as a general feature the dysfunction/damage of central nervous system is better characterized by the degree of improvement on repeat testing rather than by the absolute values of P300 amplitude and latency.
Rugg et al.[100] in a simple oddball paradigm found that their patients with head trauma had an enhanced amplitude and delayed latency of the N2 component of the responses to target tone. They interpreted this finding as a deficit of the efficiency of early perceptual categorization processes.
Curry[101] reported that patients who had suffered moderate and severe head injuries showed smaller differences between GO and NO-GO Contingent Negative Variation (CNV) trials than controls when tested some months after the trauma. Closed head injury may cause an impairment in the use of the information which permits differential response selection and also in some aspects of preparation to motor response.
Rugg et al.[35] have recently confirmed these data showing that in moderate/severe closed head injuries the patients' early CNVs ("orienting" components) did not differentiate GO and NO-GO trials while late CNVs ("expectancy" components) showed smaller GO/NO-GO differences than the control group. Furthermore the patients showed larger absolute interhemispheric asymmetries in early CNVs than controls suggesting that one hemisphere had received more severe damage than the other. No differences were found in the late CNVs neither in the N1 component between patients and controls. An important finding is that GO and NO-GO stimuli were equally "salient" for patients as they evoked frontal negative waves (300-600 msec after S1) of equal amplitude. These waves were equal in magnitude to those elicited in controls by GO stimuli. Patients resulted over-responsive to NO-GO stimuli rather than under-responsive to GO stimuli suggesting that the inhibition process may be more difficult for them than the activation one. The late CNV (1200-1500 ms) central maximum had a different relationship with RT in controls and in patients. Focal lesions of the frontal lobes are a common sequela of closed head injury. In the patients of this study 9 out of 20 had frontal damage (haematoma and/or contusion). The group of patient had an excess of perseverative errors at the Wisconsin Card Sorting Test which is sensitive to frontal lobe damage[16].

5 AEROMEDICAL DECISION MAKING IN MHI

The relationship between the aeromedical examiner and the subject in the medico-legal context is characterized by the possibility of simulation or dissimulation of a previous head trauma and related sequelae. As a consequence, the medical history as reported by the subject is not always reliable. Therefore objective and specific diagnostic procedures are of paramount importance.
Several studies in the literature examined a number of different diagnostic approaches with different degrees of sensitivity, specificity, and reliability. Nevertheless, an exhaustive diagnostic protocol with an unequivocal prognostic value has not been found yet. In fact many studies on MHI show some of the following limitations: the reliability of the documentation of trauma severity, the certitude about the absence of other causes of brain impairment, the lack of comparability due to the examinations carried out at different time intervals in different studies (in particular true longitudinal ones), the absence of evaluation of premorbid functioning, the lack of control groups and repeated measures, the inhomogeneity of the groups studied with respect to sex, age, and time since the trauma.
As a general rule in MHI, the functional changes related to abnormalities at different level of CNS should be detected. Some functional alterations, however, may not reflect a neurological damage due to the trauma if they do not appear within some time after the injury. It is not rare, for instance, that neurotic whiplash subjects may try to achieve a gain by simulation or exaggeration.
Moreover, it is possible that behavioural data are not consistent with known or assumed lesions.
The head-injured patient should be examined as soon as possible for medico-legal reasons and the examination should be repeated at least at 1, 6, and 12 months after the trauma.
In fact, we suggest that this examination comprise a neuropsychological and a neurophysiological evaluation.
A comprehensive neuropsychological evaluation should encompass a battery of tests in order to assess different functions, such as attention, memory, problem solving capability and visuo-motor ability. A battery of such might be a PASAT test, a VSR procedure, a MCST, and a multiple choice visual reaction task.
A restriction from flight duties or other skill-requiring activities is mandatory until normalisation of neuropsychological parameters.
Nevertheless, we believe that, in order to avoid an unnecessary period of restriction from flight duties and, in the meantime, an early and potentially dangerous

return to flight, there is need of following a more detailed diagnostic protocol.

In our opinion CT scans and MRI are not strictly necessary for medico-legal purposes. Furthermore MRI fails to provide additional guidelines for surgical management as compared to CT scans[3] and therefore it seems to play a secondary role in MHI. However MRI IS to be suggested in case of persistence of subjective symptoms or evidence of marked or prolonged cognitive impairment neuropsychologic evaluation tests.

Aeromedical regulations in different countries already include accurate medico-legal procedures for aircrew selection and periodical check-ups. These represent a great opportunity to carry out controlled follow-up examinations on the effects of MHI. However, it is not cost-effective to apply sophisticated diagnostic tests to all the applicants. We believe, indeed, that applicants who enter the career as either military or civil pilots (a small number with respect to the total of all applicants) should be also examined in "baseline" conditions also with a specific set of neurophysiological tests. We suggest, in particular:

QEEG with an adequate number of channels (at least 19, according to the International Standard for conventional EEG) recorded during both rest wakefulness and activation procedures (photic intermittent stimulation and hyperventilation adequately standardized);

MMEP's recorded paying special attention to the measurement of central sensory conduction times;

ERPs as the N200-P300 complex and CNV in paradigms like the "GO/NO-GO"[99], "scopeutic"[102], "distraction"[103] or "dual task"[104], which are more sensitive to subtle changes in the information processing of the brain.

Such baseline evaluation is very important for a neurophysiological evaluation of head injured patients since intraindividual variability is minimal, whereas a wide interindividual variability exists. That is even very small changes in some neurophysiological parameters with respect to baseline conditions may have a great diagnostic value

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Neurological Decision Making in Aviation Medicine Based on Electrophysiological Methods

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One main category of decisions in aviation medicine deals with the question, whether a particular person has, has still or after a trauma or illness has again the aptitude for flying. One of the differences between aviation medicine and clinical medicine is the different reliability of medical history. Patients offer their complaints and symptoms with willingness and frankness as they are looking for help. Our clients sometimes offer their medical history in a more restrictive manner. In addition aviation medicine has to give a prognosis about and minimize safety risks. And even the most willingful person cannot give a meaningful answer to the question, whether the individual risk for an epileptic seizure under special conditions is elevated or not. As input for risk assessment as for decisions concerning aptitude for flying, results of examination by clinical and technical methods compared to informations from medical history have an even higher relevance than in clinical medicine.

The task of neurology in aviation medicine ist to determine, whether a person is without disturbances of the nervous system's function and without elevated probability to show relevant disturbances in future. Besides medical history and clinical examination, decisions are based on technical methods. Concerning image generating methods, testing of higher brain functions, and sonotopographic methods neurology for the most part utilizes the service of the specialties radiology, psychology, and angiology, while application of electrophysiological methods like electroencephalography, electromyography, neurography or examination of evoked potentials are the neurological specialties own methods.

Based only on informations from medical history, an applicant for flying will be rejected if e. g. syncopes, epileptic seizures, or a typical migraine including ophthalmic or neurological symptoms, or recurrent reversible neurological symptoms are reported. Pilots or crewmembers with such a history will be dismissed from flying duty unless extensive examination and adequate treatment, if necessary, can exclude further recurrency.

Decisions about permanent malfunctions of the peripheral nervous system mainly are based on assessment of the remaining function. Electromyography and neurography in this assessment play a less important role than in the process of clinical diagnostic examination. To which extent a sensible or motoric deficit is relevant in aviation medicine, depends on the remaining ability to meet the special requirements, independent of the cause of the malfunction. A motoric deficit e. g. is more

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serious than a sensible one, a partial sensible deficit of the upper limbs more grave than of the lower limbs, and a sensible radicular syndrome of cervical nerve root 6 more handicapping than of root 8 because of the effects on precision movements of the most important fingers. Crucial in every single case will be the result of a detailed examination by flight surgeon and instructor pilot whether all relevant actions in cockpit can be performed well and safely. Growing relevance of somatosensory evoked potentials in evaluating peripheral nervous system is demonstrated in Dr. Freund's lecture. In the near future we hope to test the relevance of magnetic stimulation for our issues.

Decisions concerning higher functions of central nervous system are based on subtly differentiated psychological examinations. The results of standardized testing methods demonstrate whether a person meets the cognitive-intellectual and psychomotoric-coordinative requirements for flying duties, whether concentration is possible for long periods, or whether multiple tasks and high workload can be managed. Based on these psychological methods and on comparison with their results in initial testing it is possible to examine, whether a person e. g. after a severe head injury has achieved again the individual level of cognitive performance, whether, despite of successful treatment of substance abuse, deficits in higher functions remain, or whether deficits in dealing with workload can be found after meningitis despite of normal behavior in everyday life.

Malfunctions of the central nervous system which exclude aptness for flying are e. g. epilepsia or chronical inflammatory processes like encephalomyelitis disseminata. These groups of diseases represented by the examples own the characteristic, that symptoms are, or can be reversible and there exist shorter or even longer periods with only few or no symptoms. The probability to find symptoms by a relatively short examination during a randomly chosen period of time is typically low. Consequently these problems could even be dissimulated. In this context technical methods of examination play a major role.

Encephalomyelitis disseminata is one of the most frequent neurological diaseases. First manifestations often affect the optical system and are mostly reversible. For almost two years therefore every applicant for flying in our institute is examined with visually evoked potentials. The method is well established and provides reliable results. The average P-100-latency in our laboratory is 108 ms. Compared with the published data this is relatively high, due to the majority of young applicants of the age group 18 to 20 years in our population, as latencies definitely stabilize only at the age up to 25 yrs.

If the individual result is above 118 ms, which is 2.5 standard deviations above the average, we assess a person as unsuited for flying. This even with empty medical history and inconspicuos clinical examination. Our few-case-experience with additional magnetic resonance imaging was unsatisfactory. Even if no intracerebral lesion can be detected, the detection of optical system affection by VEP remains, and the presence of an chronically inflammatory process cannot be excluded. Up to now we exclu-

ded about 0.8 % of the applicants due to this constellation of isolated finding of abnormallly prolonged VEPs.

For persons already in flying duty the situation is different. In this group up to now visually evoked potentials are examinded only if indicated by suspect medical history or abnormal findings in physical examination. Finding of abnormal VEPs in these cases have to be followed by extended examination including magnetic resonance imaging, electrophysiological tests of other subsystems, and examination of cerebrospinal fluid for oligoclonal immmunoglobulins etc..

We are convinced of the special importance of electroencephalography (EEG) in military aviation. Among the factors which can lower the brains electrophysiological stability and the threshold for epileptic activity, there are lack of sleep, change of day-night-rhythms, exhaustion, imbalance of electrolytes, hypoglycaemia, hyperventilation, hypoxia. All these factors can occur and have to be considered under the special conditions of military missions. The lower a persons individual treshold for epileptic activity is, the more important become these factors. G-load e. g. leads to periods of decreased cerebral blood flow and consequent cerebral hypoxia, thus facilitating epileptic activity. Long-haul flights without adequate recreation times or conditions during missions in crisis or conflict lead to alterations in day-night-rhythms, lack of sleep, and exhaustion. These conditions elevate risk of epileptic activitiy in anyones brain. Signs of a lower threshold for epileptic activity therefore have to exclude from any duty in military flying.

Photic effects similar to strobelight may result from passing short wave cloud formations with high velocity as they can be provoced by helicopter rotors under special light conditions. Signs of lability under photic stimulation therefore have to lead to rejection concerning flying of helicopter or fighter jet.

EEGs with relevant, i. e. moderate to severe general alteration lead to exclusion from flying duty, but in our experience don't play an important role in decision making, as they mainly are caused by conditions like severe alterations of metabolism, intoxications, severe infectious diseases which exclude flying duty themselves. An only light general alteration needs to be controlled, until evidence of beeing a non-pathologic variation can be established. Is it found although a normal pre-EEG exists, a pathological process has to be suspected, until the contrary has been proven.

The finding of focal alterations of EEG causes indication for image generating methods, especially if there has been found a normal EEG before or if there are focal clinical signs as well. E. g. an intracranial tumor, malformation, brain haemorrhage, or stroke has to be suspected. Fleeting asymmetria exclusively in the occipital region and consisting only of alpha-reduction or -rarefication on the other hand, we consider to be a harmless and/or physiological variation without need of any consequences.

The electroencephalographic finding of alterations typical for epilepsia leads to the decision to exclude the person from flying, even if there are

no other corresponding informations, signs or findings at all. If it came to any severe reversible alterations in behaviour of that person or, worst, to flight mishaps caused by this person, this would be extremely problematic. It hardly at all could be proven, that the incident had not been caused by the abnormal EEG-activity.

The main task of electroencephalography in aviation medicine in our opinion is to identify persons with an individually higher electrophysiological lability, which is a lower threshold for abnormal activity of the brain. These persons under conditions of military duty bear a higher risk of developing epileptic phenomena, even if they stay asymptomatic under conditions of everyday life.

An important and not yet solved problem consists of the wide range between definite normal and definite pathological findings in EEG, resulting from the method itself and the variing correlation between findings and relevant consequences. It is difficult to give statistic data, because the number of problematic findings depends on the definition of abnormal, but unspecific and not yet pathological findings. Estimated roughly, the population examined in our institute in more than 90 % of the cases have normal EEG-activity of alpha-type or variants, which doesn't show abnormal alterations even under provocation with hyperventilation during 4 minutes and photic stimulation with strobelight of variing frequencies. Definitely pathological alterations are found in far below 1 %. Problematically with unspecific abnormalities are about 10 % of the 1400 EEGs we examine every year.

To demonstrate the consequences, EEG-examination in our institute has for applicants for military flying, the following results are reported. Of 837 consecutively examined applicants in a time period of 17 months, who passed psychological testing prior to medical examination 66,5 % (557) have been accepted for military flying, 33,5 % (280) have been rejected. The rejections in 28,6 % (80) of the cases were caused by neurological or, in a small minority, by psychiatric findings, in 71,4 % (200) due to abnormal findings in the other medical specialties. In Neurology/ Psychiatry 70 % (56) of the 80 rejections were caused by alterations in EEG, only 30 % (24) by other reasons. So the risk to be rejected due to alterations in the EEG was about 6,7 % (56). On the other hand 93,3 % (781) of the examined applicants had a inconspicious EEG. The EEG findings leading to rejection in a minority of cases were focal alterations, but mainly paroxysmal dysrhythmia and change to moderate to severe general alteration after short period of hyperventilation or with retarded normalization after hyperventilation.

These unspecific abnormalities are widely differing in quality and quantitiy, but do not reach dimension of the pathological findings mentioned above. The possible relevance of the alterations in the field of aviation medicine may be demonstrated by the following case report. A 20-year-old applicant for flying had an empty medical history and a normal neurological physical examination. He showed unspecific alterations in the form of paroxysmal dysrhythmia of higher amplitude in the spontaneous EEG. If e. g. a headache patient showed such al-

terations, we wouldn't have been that much concerned, while in similar cases we negated aptitude for flying. As this applicant was rated as performing above average in psychological testing prior to medical examination, he was given the chance to have his EEG done again the following day. Then, without any clinical sign, his EEG showed multiple fleeting spike-wave-complexes.

For these unspecific alterations, which are not that important for clinical neurology, but are already important for neurology in aviation medicine, up to now we miss acceptable categories and gidelines for evaluation and decision. In the absence of other aids and rare informations in literature for long time we only decided based on clinical experience and global impression, which was unsatisfactory. Consequently we tried to define these unspecific alterations in EEG better and to develop an instrument, to make our own decisions more objective and reliable. To create a alteration score, we assigned points to the defined criteria in a way, a score of 10 and more points would indicate unacceptable alteration. The suggested criteria and the assigned points are compiled in the demonstrated table.

Two examples may demonstrate, how this score is thought be helpful. At first, the occurance of moderate general alteration (4 points) only under hyperventilation of more than 2 minutes (1 p.), which normalizes within 1 minute after hyperventilation (1 p.) with a normal EEG in other sections leads to a score of only 6 points, as this alteration is thought to be a still normal reaction to hyperventilation, which doesn't have consequences in categories of aviation medicine.

On the other hand, dysrhythmic alterations with amplitudes of 150% compared to inconspicious sections of the EEG (4 p.), which occur after less than 2 minutes of hyperventilation (4 p.) and normalize only after more than 1 min after end of hyperventilation (2 p.) exceed the limit of 10 points, as they are judged as an unspecific risk in the sense of a lowered threshold for epileptic activity.

This score is not thought to "measure" alterations, but it is a device, which can help to reduce subjectivity in the process of decision making. Although not established well, we dared to present this score, as we expect helpful criticism and suggestions.

Electroencephalography alteration score GAF IAM
Abnormality/Dysrhythmia in spontaneous EEG with share of <1%: 2   <5%: 4   <10%: 6   10-50%: 8   >50 %: 10
Abnormality/Dysrhythmia under hyperventilation (HV) of >2 min: 1   <2 min: 4   <1 min: 6 with a share of   < 2%: 1   < 5%: 2   > 5%: 4
Abnormality/Dysrhythmia under photic stimulation (FS): 4 with a share of   < 2%: 1   < 5%: 2   > 5%: 4
Normalization under continued HV: 0   < 1 min after HV: 1 < 2 min after HV: 2   > 2 min after HV: 4 under continued FS: 0   <1 sec after end of FS: 2 < 2 sec after end of FS: 4   >2 sec after end of FS: 6
Dysrhythmia / Unregularities (graphic elements, with Amplitude > 33 % of max. amplitude of neighbouring : 4 unconspicour sections of EEG, or with Frequency > 1 Hz: 1   > 2 Hz: 4 differing from normal sections of EEG not paroxysmal, from neighbouring activity not differentiated well, or starting out of already unregular activity, changing gradually: 1 paroxysmal, differentiated sharply from preceding or following activiy, abruptly, sharp 4
General alteration   light: 2   moderate: 4   severe: 6
Focal alteration   inconstant: 2   constant: 4 exclusively occipital: 2   other localisation: 4 amplitude reduction: 2   alpha-rarefication: 4 theta: 6   delta/beta: 8
Activity specific for epilepsy 10

We also see a lot of other work to be done with EEG, since we are convinced, that the mentioned unspecific sub-clinical alterations in EEG-activity are of high interest in aviation medicine. Not yet demonstrated definitely, as far as we know, is the corre-lation of behavior of intra-cranial blood flow under g-load and EEG-alterations. We plan, as a first step, to exa-mine intracranial blood flow under g-load in the centrifuge with a helmet mounted trans-

cranial doppler device. Additionally we plan to measure hyperventilation provocating EEG-alterations by capnometria in blood and/or respiratory system or, much more convenient, by the effect on cerebral blood flow demonstrated by transcranial Doppler-sonography. Finally we intend to demonstrate a suspected correlation between alterations of EEG depending on decrease in cerebral blood flow induced by g-load on one side and induced by hyperventilation on the other. Should this be proven successfully, EEG under hyperventilation would be a simple but adequate method to predict alterations of EEG-activity under g-load.

THE E.E.G. IN THE EVALUATION OF APPLICANTS TO AIRCREW MEMBERS

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1. INTRODUCTION

The E.E.G. has been used, since its beginning, as a tool in selection of aircrew personnel. Knowing that, even in epileptic patients, the E.E.G. in a great majority of cases doesn't show abnormalities, the problem is raised on the meaning of such method in the selection of aircrew candidates.

In the other hand we must agree in the definition of a "normal" E.E.G., and what are the meanings of certain abnormalities in an individual that says that he/she is healthy and denies in his/her clinical history, epilepsy, febrile convulsions, headaches and head traumas.

According to Niedermeyer and Lopes da Silva (1), the usefulness of the E.E.G. in aircrew selection is that we'll have a record to compare in case of need of repetition of E.E.G.

In the Portuguese Air Force the selection is seriated, being the neurological observation one of the last one's, and only one small part of all applicants submitted to it. The evaluation consists on a clinical history, in which the denial of all pathology is the rule (they are all voluntary), neurological examination and an E.E.G., 30 minutes duration, in the 10-20 system (since 1990), with two hyperventilations and one photic stimulation. Until 1989 the montages used are shown in Fig 1. In Fig 2 are the montages used after 1990.

2. METHODOLOGY

We had access to E.E.G. reports since 1972 to 1993, performed to the following applicants: pilots (Air Force Academy, Navy, Angola, Mozambique, Cabo Verde and Sudain), navigators, HALO and HAHO paratroopers and hipobaric chamber crewmembers. Ages were between 17 and 30 years. The total of records was 3305. The analysis of the records was visual.

The E.E.Gs. were performed in two different machines: untill 1989 was used a Nihon-Kohden with 8 channels, and since 1990 a Nihon Kohden model EEG-5210F, with 10 channels.

For the purpose of this work we considered only as abnormals the records presenting spikes, spike and wave complexes and focal slow activity, as we used nowadays.

The Portuguese Air Force standards, under the paragraph 63, is considered unfit the E.E.G. with permanent alterations, whatever this can mean (?), but that gives a very wide margin to the interpreter.

Some problems were raised since the beginning of this work:

(1) the different doctors who performed the reports - two between 1972 and 1978, one from 1979 to 1987 (two in 1986) and two (one of them myself) since 1988 until now;

(2) time of the year, usually the majority of applicants is present at the Aeromedical Center in July and August, which are very hot months in Portugal, and with lack of sleep, both causes conducting to somnolence with the resulting patterns in the E.E.G.;

(3) last but not least, they are very young, with records sometimes revealing some inmaturity, and so, with some problems in interpretation.

To analise the record we divided them in two groups: those presenting spikes, spike-wave complexes and those with focal slow activity, the majority of wich was in the temporal regions, either left or right.

During the first period (1972-1978) were considered also as abnormals,

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the EEGs that showed generalized slow activity, sharp and/or slow waves, these ones presenting sometimes in paroxysms, simmetrical or assimmetrical during rest or hyperventilation.

3. RESULTS

What we can notice in first place is the variation, in total numbers, of the EEGs considered abnormal, in the years 1972 trough 1978 with percentages that varied between 17,4% (1972) and 33,3% (1977), compared with the years until 1993: 1.1% (1989) and 11,7% (1986); in the year of 1986 the EEGs were reported by two different neurologists, one of them not trained in aircrew selection.

Analysing this data with our actual standards the number of abnormal EEGs would decrease to more or less one half. This is shown in Table 1, where we can see also the absence of any significative difference after 1979.

Since 1972, and considering all this different criteria, only one pilot was observed with seizures (his EEG as applicant was completely normal). This pilot was. after the examination, considered definitively unfit for flying duties.

In 1993 a candidate was disqualified because his EEG showed anterior beta activity; there was no other abnormal or drowsiness related activity. It was suspected the possible ingestion of drugs; he was considered unfit only after psichiatric evaluation.

We don't know if any of the candidates, considered as unfit on EEGs basis, had suffered, at any time an epileptic seizure. It can be an interesting work, in a future.

4. DISCUSSION

We think that differences in the rate of elimination are only due to the different criteria used by the electroencephalographers

Other studies show that the percentage of candidates with abnormal EEGs is very low and similar to ours, since 1979 (Table 2).

The actual standards seem to be reasonable, because those alterations considered as abnormals, are the most common seen in the people with pathology. At the same time, we are aware that those with normal EEGs can develop seizures at any time, but this is a risk that we have to take.

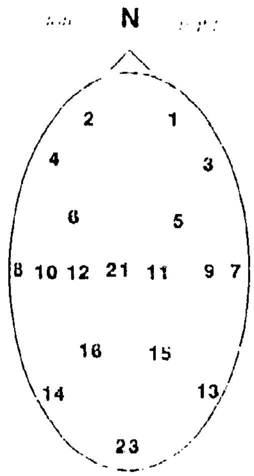
5. CONCLUSION

The reason for unfitness for crewmember, mainly pilots, is flight safety.

Even if a "normal" EEG has no clinical significance in ruling out epileptic or other Central Nervous System pathology, the initial record stays as a standard for further needs.

In the Portuguese Air Force Aeromedical Center, an EEG is performed if the crewmember suffers any loss of consciousness (except G-LOC) and after head trauma, in this case, simultaneously with neuro-psychological evaluation, skull X-rays and , if needed, a CT Scan

The economical problem, raised by some authors, in our case is despicable, due to the small number of records performed each year.



REFERENTIAL		BIPOLAR			
M 1	*M 2*	*B 3*	*B 4*	*B 6*	*B 8*
5	1	1-5	1-3	1-3	9-11
6	2	2-6	2-4	2-4	10-12
7	3	5-11	3-7	7-9	11-21
8	4	6-12	4-8	8-10	12-21
11	9	11-15	7-13	9-11	13-14
12	10	12-16	8-14	10-12	15-16
13	15	15-23	13-23	11-21	15-23
14	16	16-23	14-23	12-21	16-23

TIME CONSTANT=0,3 sec
AMPLITUDE=50 microVolts/cm
PAPER SPEED=1,5 cm/sec
ELECTRODE RESISTANCE= >0,5KOhms

fig.1

M 1	M 2	B 3	B 4	B 5	B 6
Fp2-Cz	Fp2-Cz	Fp2-F4	Fp1-Fp2	F8-F4	T4-C4
Fp1-Cz	Fp1-Cz	Fp1-F3	Fp2-Fp1	F4-Fz	C4-C3
F8-CZ	F4-Cz	F4-C4	Fp2-F8	Fz-F3	C3-T3
F7-Cz	F3-Cz	F3-C3	Fp1-F7	F3-F7	T6-P4
T4-Cz	C4-Cz	C4-P4	F8-T4	C4-Cz	P4-Pz
T3-Cz	C3-Cz	C3-P3	F7-T3	C3-Cz	Pz-P3
T6-Cz	P4-Cz	P4-O2	T4-T6	P4-Pz	P3-P5
T5-Cz	P3-Cz	P3-O1	T3-T5	P3-Pz	T6-O2
O2-Cz	O2-Cz	O2-O1	T6-O2	T6-O2	O2-O1
O1-Cz	O1-Cz	O1-O2	T5-01	T5-O1	O1-T5
HPN			HPN		PhSt

AMPLITUDE - 50 micro V/cm ELECTRODE IMPEDANCE <0,5 KOhms
TIME CONSTANT - 0,3 sec
PAPER SPEED - 1,5 cm/sec

fig.2

TOTAL EEG	EEG ABN	EEG S, SW	EEG FS	YEAR	EEG ABN % TOTAL	EEG S,SW % TOTAL	EEG FS % TOTAL	DIFFERENCE ABN - SSWFS
390	70	22	11	1972	17,4	5,6	2,9	-47
343	66	31	13	1973	18,1	8,5	3,6	-22
270	64	20	20	1974 5	23,7	7,4	7,1	-24
101	23	4	7	1976	22,7	3,9	6,9	-12
33	11	2	4	1977	33,3	6,0	12,1	-5
137	34	8	10	1978	24,8	5,8	7,2	-16
131	5	2	2	1979	3,8	1,5	1,5	-1
155	9	3	6	1980	5,8	1,9	3,8	0
130	2	0	2	1981	1,5	0	1,5	0
143	6	3	3	1982	4,1	2,1	2,1	0
184	10	4	6	1983	5,4	2,1	3,2	0
180	3	1	2	1984	1,6	0,5	1,1	0
137	10	10	0	1985	7,2	7,2	0	0
94	11	8	3	1986	11,7	8,5	3,1	0
112	9	6	3	1987	8,0	5,3	2,6	0
136	7	0	7	1988	5,1	0	5,1	0
175	2	0	2	1989	1,1	0	1,1	0
151	9	0	0	1990	5,9	0	5,9	0
112	4	0	4	1991	3,5	0	3,5	0
82	3	1	2	1992	3,5	1,2	2,4	0
93	2	0	1	1993	2,2	0	1,1	1
3305	361	124	121	TOTAL				
	10,9%	3,8% 34,3%	3,66% - 33,6%	% T NAN				

TABLE 1

AUTHORS	PLACE /YEAR	TOTAL EEG NUMBER	% ABNORMALS
LETOURNEAU & al	PENSACOLA 1977	28656	0.12
RICHTER & al	BROOKS 1971	2947	2.9
RABOUTET & al	PARIS	6700	2.5
A. PACHECO SILVA	BRASIL 1977	1000	9.5

TABLE 2

Clinical Basis for Aeromedical Decision-Making: The EEG Example.

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SUMMARY

The EEG, electroencephalogram is used as a test in aircrew selection. Given that the natural history of the seizure disorders has been described,[30] the validity of this practice is questioned and potentially more rewarding applications of the EEG suggested.

System reliability is a major component of aircraft system performance. In military aviation both are central nervous system dependent. In aircrew assessment and management the EEG, electroencephalogram has traditionally played a major role[40, 48,61,78]. Advances in technology, data retrieval, storage, presentation, processing, interpretation and assessment make this an appropriate time to review the place of the EEG in aeromedical decision-making and research.

Present system reliability targets are of the order of a significant failure in $1:10^{-7}$ hours in commercial aviation, $1:10^{-6}$ hours in the military and in practice of $1:10^{-5}$ hours in general/private aviation[12]. With these targets why have EEGs been performed? As a form of epilepsy screening[2,3]; in an attempt to predict flying aptitude[39,44,46, 70] and as a baseline for future reference[29, 71,77]. The effort expended and the costs incurred to provide the few records required for useful later comparison has been considerable[18,19, 66]. Any correlation between initial EEG and subsequent aptitude has not been pursued, leaving seizure screening as the justification for present EEG programmes[52,56,61].

To be effective, screening requires a major, defined target health problem the natural history of which is defined and understood. It has to be detectable in the latent or early symptomatic phase. An examination or test of proven performance in Bayesian terms of sensitivity and specificity has to be available, applicable within practical and economic constraints and acceptable to the target population. Treatment, who to treat and treatment facilities have to be agreed[86].

Aircrew seizure is a problem[45, 62]. The prevalence of epilepsy in the population from which they are drawn is undoubted. Excluding febrile convulsions under 5 years of age 2.3% have had one seizure[27], 0.65% more than two[31]. However the risk of initial seizure in those aged 20-60 years [including many with neurological conditions that would preclude flying] is 10: 1,000 or 1% over 40 years[30,32]. That is 0.025% per year, $2.85:10^{-8}$ hours. This can be compared with the male heart attack rate, aged 23-34 years, of $5.1:10^{-8}$ hours [rising to $31.2:10^{-8}$ hours between 35-44 years; $77.6:10^{-8}$ hours between 45-54 years and $156.4:10^{-8}$ hours between 55-64 years of age][81]. Actual experience in aircrew candidates who have yet to have a first seizure are of risk rates below the $2.85: 10^{-8}$ hours level[19,21,29, 47,62,63,64,67], well within 10^{-6} military and 10^{-7} hours civilian risk targets, suggesting that a

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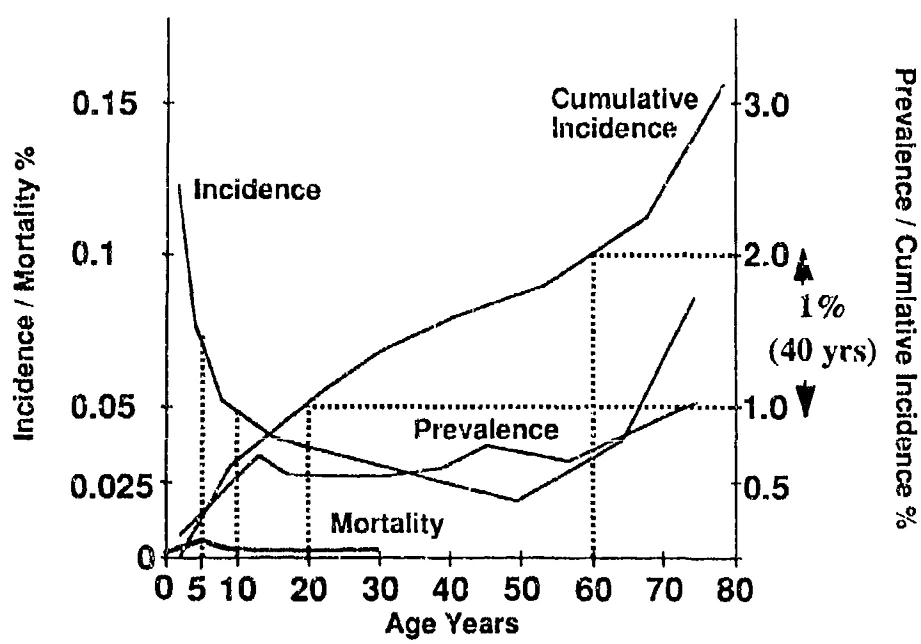
careful neurological history alone, taken during the initial medical assessment, would provide screening at an order of magnitude better than present risk target levels require.

The second screening requirement is an understanding of the natural history of the target condition. For epilepsy this is encapsulated in the Hauser-Annegers diagram [fig.][30]. Once past puberty and into adult life the initial, spontaneous seizure rate is low[21], well within present risk targets. The key is the exclusion of prior convulsion, of a family history of epilepsy in a close relative, of a significant head injury or other past cerebral insult[54].

What of "abnormal" EEG appearances in clinically normal subjects?[10,14,20,41,49,68,78] The literature indicates these to be present in 0.5-35% of the non-epileptic, "normal" population[3,4,9,11,24,26,29,33,43,46,59,60,67,79,88]. The risk of subsequent epilepsy in non-epileptic subjects who display epileptiform EEGs is reported to be between 1.5 - 5.0%[29,33,67,80]. The prognostic value of the classical spike/wave pattern in asymptomatic individuals has been questioned and a later epilepsy risk little different from that of the general population suggested[67,68]. The definition of what constitutes an "epileptiform" EEG and which EEG abnormalities are prognostically sig-

Epilepsy
Hauser-Annegers Diagram[30]



Rochester 1935 - 74 *(Annegers, J.F.)*

nificant for subsequent seizure remain matters of debate[1,55,58,68,69,88]. Meanwhile some 50% of clinical epileptics have initially normal interictal EEGs, serial EEGs being necessary to reduce this "false normal" population to the 8% level[1,69].

EEG abnormalities not associated with epilepsy, where "epilepsy" is defined as the occurrence of and propensity for subsequent spontaneous seizure, include: 6/sec spike and wave; 6 & 14/sec +ve[14] and small spikes; SREDA [sub-clinical rhythmic discharges in adults][41] and BETS [benign epileptiform transients in adults] among the mid-temporal rhythmic discharges; and slow wave responses to overbreathing[68].

EEG patterns which are associated with epilepsy are <3/sec spike & wave; focal spikes and polyspikes; rhythmic focal slow waves. The latter are often associated with already symptomatic intracranial space occupation.

In this uncertainty, of the many potential epileptic precipitants, sleep deprivation might have been the most appropriate in the military situation to induce seizure or elicit seizure markers[17,43,85]. In practice recourse has been to intermittent photic stimulation[8,22,25,37,51,83] to evoke photo-convulsive, "flicker-induced", "helicopter" epilepsy[5, 23,35]. The trawl of epileptiform recordings may be tripled by such aggrevation[29]. But of common EEG photic responses, the Following Response, the Photo-myoclonic Response and occipital spikes are not associated with epilepsy, photo-induced or otherwise[6,15,16, 68].

Only the Photo-convulsive Response, if demonstrated, is significant. Its threshold varies in and between individuals and it is compatible with an otherwise normal EEG. It is a generalised spike/spike & wave discharge which paradoxically is maximal frontally. Its frequency is independent of the flash frequency used [10-20Hz being the most likely to elicit it] and the response continues after the photic stimulation has been discontinued[7,8].

EEG photic responses are common in normal subjects[6,82]. EEG photosensitivity does not mean epilepsy[15,16,57,87]. Photoinduced paroxysmal responses are observed in the EEGs of <4% of normal subjects, <15% before puberty[42,53]. Photoinduction may be achieved between 5-20Hz, but is maximum at 12Hz[36]. The photosensitive effect is best aborted by closing one eye. Closing both may precipitate seizure[36].

In established epilepsy photogenic stimuli are the commonest sensory seizure precipitants[1,13,22,28,50,65,83]. But photoprecipitated seizures usually present in childhood or adolescence[38,87]. Later onset photosensitive epilepsy, with first seizure over 20 years of age, is rare[7,38,87].

Pure photo-evoked epilepsy[6] is a clinical reality, despite academic reservations[35]. It is characterised by the EEG photoconvulsive response[8]. Though usually abnormal, the EEG may be normal, the photoconvulsive response appearing "out of the blue". A single EEG cannot be relied upon to detect the photoconvulsive trait. Thresholds vary both for the EEG response and for the clinical photogenic seizure, from person to person and from time to time in any one individual[34,35]. Age, Past and Family History are again the keys to detection and are the foundations of effective aircrew screening and selection.

What of the EEG in aviation medical practice? Because an abnormal EEG has meant de-

selection and most rejected candidates have not been followed up, the sensitivity and specificity of the EEG in the screening setting has yet to be established. In terms of risk assessment for seizure Age, Past and Family History remain the significant criteria. Birth insult and congenital factors lead to seizures in the first year. Febrile convulsions occur up to five. The "genetic" epilepsies present by 20. But, as if difficulty in evoking the photo-convulsive response were not enough, the sting in the tail for the EEG aircrew screener is that during the 40 "flying years", aged 20-60, when <1:100 will suffer a first seizure, it will be in response to alcohol and head injury, infection and tumour, for which no EEG risk markers may be present at the time of initial assessment.

What past reliance on the EEG as a test, rather than its use as a valuable tool in the clinical situation, has achieved is to divert attention from clinical reality and the EEG's other potential applications[72-6]. The new EEG technologies now deserve review of their utilization and organization lest the considerable budgets already expended on re-equipment be wasted on expensive reduplication of simple, cheap, practical and effective clinical methods.

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SPINE INJURIES. UP TO DATE EVALUATION IN AIRCRAFT EJECTIONS.

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INTRODUCTION

Spinal injury during aircraft egress has been a well known phenomenon since the early days of flying, though at that time usually secondary to ground impact. However, the development of High Performance Aircraft (HPA) has forced the consequent development of high performance ejection mechanisms. These modern ejection systems have functioned superbly with the latest generation mechanism allowing 91.1% survivability when egress takes place above 500 ft from ground level and 79.2% pilot survival rate when egress is undertaken at flying level less than 500 ft. However, while the overall sucess rate of 88% has resulted in many more pilots surviving an egress experience, 21% of these flyers have been shown to suffer some degree of significant spinal injury (vertebral compression-fracture) during egress, potentially theatening their ability to return to the cockpit (1,2).
Modern HPA, with their ability to inflict inmediate and sustained high +Gz forces to the cockpit environment challenge the flight surgeon now as never before to carefully and successly evaluate the pilot who has suffered egress-related spinal injury in order to determine whether it will be safe for the flyer to return to such an environment (3,4).
This challenge is made even more pressing by the fact that pilots who eject are often well-trained, experienced flyers whose potential lost services, either due to permanent disqualification from flying duties or due to further, additional spinal injury, represent a significant potential loss of valuable human resources to NATO Air Forces, already facing the loss of key personnel and resources due to today's economic pressures.
These factors make it imperative that all of the modern medical means at hand be utilized in the analysis of post-ejection spinal injuries.

Anatomically a wide variety of vertebral fractures and fracture classifications have been described. Prognosis may be assessed according to stability criteria and aeromedical experience (5,6,7,8,9).
In the past the vertebral column has been relatively inaccessible to clinical evaluation. Today, however, modern radiologic techniques can provide the diagnostic tools that enable an accurate

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assesment of the vertebral and paravertebral spine and thus help predict the possible pathological impact of future exposure to +Gz. Although plain X-rays, the traditional method of st 'ying spinal natomy, still supply very valuable information, more advanced techniques should have a definite role in the diagnosis and prognosis of the injuries caused by ejection.
Magnetic Resonance (MR), with its excellence anatomic contrast r solution, provides the radiologist the premier tool for assessing the spinal and paraspinal structures most vulnerable to injury by higher than normal G-forces in a injured pilot who is being evaluated to return to the cockpit (10,11,12).
It is essential that the aeromedical community work closely with radiologists, employing the latest diagnostic methods and data in order to best evaluate spinal injuries and thus c rectly predict the extent of injury so that flying duties can be resumed, either in the former aircraft or in another flying class (9,13,14).

A' EDICAL DISPOSITION

Medical standards for flying duties include a general approach to the potential complications and disabilities that are ofte direct consequence of ejection, most of these being vertebral fractures or dislocations.
The SAF standards allow for class I a maximum of 10% limitation of range of motion according to the degre of rotation, flexion and extension or vertebral fracture with angle of compression not greater than 25 degrees.
All current regulations concern the evaluation and the measurements of a variety of signs and symptoms, usually related to compression fractures and to history of disabling episodes of back pain associated with significant objective findings.
A review of 8 NATO coun s aeromedical standards for ne and musculoskeletal diseases or injuries revealed references to healing, symptoms, neurological disturbances, disc involvement and functional integrity of the spine.
These factors, especially the last two, cannot be properly evaluated by utilizing solely conventional radiological studies. In conventional radiography, it is often difficult to rule out many boney and soft tissue lesions as the etiology of vague clinical findings. Even more importantly, it is difficult to adequately assess the significance of a positive radiologic finding that has no current clinical correlation with physical exam. MR however, is much better in reveling anatomic relationships of various bone and soft tissue lesions and thus can best discern those with clinical and prognostic significance from abnormalities that might appear on regular X rays but, in fact, are of no consequence (11).

DISCUSSION

The thoraco-lumbar spine and the segments between T10 and L2 are the most commonly affected region as a consequence of aircraft egress (1,5).
In relation to the type of fracture originated at thoraco-

lumbar level and from a biomechanical point of view, these lesions may be classified in 7 different categories: 1) Compressive flexion, 2) Distractive flexion, 3) Lateral rlexion, 4) Translational , 5) Torsional flexion 6) Vertical compression and 7) Distractive Extension (6). Denis has the concept of the three column spine. The posterior column or posterior ligamentous complex; the middle column, including the posterior longitudinal ligament, posterior annulus fibrosus and posterior wall of the vertebral body; and the anterior column, consisting of the anterior vertebral body, anterior annulus fibrosus, and anterior longitudinal ligament.

Major spinal injuries are classified into four different categories, all definable in terms of the degree of involvement of each of the three columns. Each type is also defined in terms of its particular stability (7).

The "compression fracture" is basically stress failure of the anterior column with intact middle column. The "burst fracture" indicates failure under compression of both the anterior and middle columns. The "seat belt type" sp fracture is the result tailure of the posterior and middle columns under tension with intact anterior hinge. In "fracture dislocations" the structures of all three columns fail from forces acting to various degrees from one or another direction.

The most frequent compression fracture injury is the compressive flexion or anterior wedge compression. This is due to the combined effect of compression secondary to the torque force and longitudinal acceleration and hyperflexion of the pilot.

The worst prognosis of these fractures are those that involve the middle and posterior Denis' columns which ussually result in acute or chronic progression to some degree of spinal deformity, often with chronic pain or neurological involvement.

From a practical point of view one may consider three types or categories of vertebral injury with progresively worsening prognosis.

Type I: Fracture of anterior wedge only.

Type II: Anterior and middle column involvement.

Type III: All columns affected.

Type I fractures very rarely present neurological involvement unless multiple vertebral fractures occur. Fortunately this is the most common vertebral injury. The prognosis of type I lesions without neurological impairment is very favourable, as it has been estimated that [illegible]0% of pilots return to flying duties (9) after a follow-up period of between 3 and 6 months.

Type II and type III are more likely to progress to instability, rapid onset vertebral deformity and concomitant neurological involvement (8).

In the past the differentiation of these three types of lesions has been supported primarily by conventional radiological exam. However the presence of lesions at the posterior medulary canal and the presence of post-traumatic myelopathy and extramedullary cord compromise as a result of mass effect such as that caused by displaced bony fragments, fluid collections (including epidural and subdural hematomas) and

penetrating objects, were often missed by simple radiology (10). These additional complications would be evident on MR. Table 1 shows classification of diagnostic approach according to reliability of each exam in various injury locations.
In addition, MR gives us information regarding a wide spectrum of cord changes, from concussion to complete cord transection. The spinal cord reacts to trauma quickly and dynamically with hemorrhage, enzymatic cord destruction, and superimposed vascular insult. Increasing cord compression results in a progression of injury through three basic types of lesions: type A - predominant gray matter cavitation, type B - white matter large fiber destruction predominates, and type C - severe, combined gray and white matter lesion in a connective tissue scar. A major advantage of MR is its ability to show the cord itself and its relationship to sourrounding structures. Cord edema and hemorrhage frequently occur after spinal trauma, with cord edema begining within minutes of injury and lasting for as long as 20 days. MR is the diagnostic method of choice, having been shown to have a high sensitivity for detecting edema and hemorrhage with the ability to differentiate the two (13). MR is superior to CT in the visualization of the spinal cord and the detection of cord injury (10,11,12).

Pilots who have sustained spinal cord injury may later undergo clinical deterioration or neurologic function secondary to post-traumatic progressive myelopathy .

The radiologic approach in diagnosing traumatic discal lesion or epidural hematoma should include CT myelography or MR, especially in the case of potential neurological injury, traumatic disc herniation or ligament involvement.
MR imaging and bone scan with TC99 are useful in ruling out vertebral injury in individuals with symptoms, but with negative or inconclusive conventional radiologic results (9,14).

Due to the lack of routine, serial MR studies applied to the flying community there is very little experience in the assessment of the pilot subjected to acceleration forces along his flying career utilizing this imaging technique. Thus it is unclear whether or not MR could be a good predictor of the potential spine impairement due to repetitive high G exposure. Cleary, the opportunity for further study is available in this particular field. A prospective protocol has been stablished since January 1994 in the SAF in order to evaluate the real value of the MR in precocious detection of spine lesions in pilots who are exposed to a high G environment.

CONCLUSIONS

1. The clinical assesment of the pilot who suffers an aircraft ejection must include a complete neurological exam and conventional radiological studies, but is not complete without MRI in order to rule out medulary involvement and assist in assessment of

prognosis of the injury.

2. MR and Bone Scan should be performed in all symptomatic patients with inconclusive traditional radiological exam.

3. The lack of current data available regarding MRI in pilots should result in the undertaking of prospective studies in order to develop experience in utilizing this technique, both to better assess postejection injuries and to potentially predict the development of future injury secondary to chronic exposure to the high G environment.

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INJURY LOCATION	**DIAGNOSTIC EVALUATION**
Medular	1. MR
Intradural	1. MR 2. Myelography with CT
Extradural	1. MR 2. Mielography with CT
Bone structures	MR and Simple radiology

Table 1. Radiologic examination of choice in evaluating various vertebral injuries.

Clinical Practice, Diagnosis and Therapy of Intervertebral Disk Lesion
Importance to Fitness for Military Flying Duties

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The spine is the central organ of our locomotor system. According to BROCHER(1957) it performs four main functions such as:
- protecting central nervous system,it envolves
- providing support and stability to the trunk,
- facilitating motion,
- taking, absorbing, and distributing loads within the body as a kind of elastic spring.

The functional unity of the spine is provided by the so-called intervertebral motor segment, according to JUNGHANS. It applies to the motion spaces between two vertebrae. The segment is made up by the intervertebral disk(discus intervertebralis), the ligamentum longitudinale anterius et posterius, the intervertebral joints, the ligamenta flava and the spine channel's space parts situated on the level of the segments, moreover, the spaces between the adjacent transverse processes and the spines of a vertebra (Canalis spinalis, recessus lateralis), as well as ligamenta interspinalia and supraspinalia. The motion segments put up with static as well as with dynamic loads.

1. Physiology and Pathology of the Intervertebral Disk (ID)

The largest individual component of the motion segment is the intervertebral disk. It determines the configuration of the intervertebral space at rest, under load conditions and when in motion. By its specific elasticity depending upon its water content, the nucleus gelatinosus exercises pressure in all directions, namely upon the adjacent vertebrae as well as on the surrounding fibrous ring.
Under load conditions, the intervertebral disk acts as a buffer, absorbing the forces which are affecting it in axial sense, and curbs the bending,winding, and shearing forces. Sommation of all the motions occurring in the different segments make up the overall mobility of the spine.
Definite diagnosis of cervical or lumbar prolapse of the ID is of decisive importance to the ability for military flying duties, in our opinion.

The intervertebral disk consists of connecting tissue composed mainly of anulus fibrosus, the fibrous tissue, and of nucleus pulposus which is the basic substance. Anulus fibrosus is firmly linked to the adjoining corpus vertebrae's basic and covering plates. Ligamentum longitudinale anterius et posterius strengthen the boundary layers of the intervertebral disk.

The most important components of the intervertebral disk are: water content, collagen, (type I in anulus fibrosus, type II in nucleus pulposus), basic substance (proteoglycanes, mucopolisacarides) and cells of connecting tissue (about 20% of the total volume).

According to PÜSCHEL (1930) and KEYES/COMPERE (1932), water percentage of the nucleus pulposus of the mature fetus is 88%, as referred to an 18-year old person it is 80%, as for a 77 year-old person it is approx.70%. The decrease of water content also reduces the turgor of the intervertebral disk and thus the elasticity, the resulting differences of pressure provoke a deterioration of metabolism and a modified composition of the liquid in between the intervertebral disks. Thus the mechanical and dynamic load capacity of the intervertebral disk will also be reduced.
According to HASSLER (1969) the intervertebral disk is nourished by vascularization essentially taking place at birth but which is disappearing during the the first months of life. According to KRÄMER's theory (1986), the intervertebral disk is nourished afterwards by way of osmosis and diffusion depending upon pressure between the disks. According to NACHEMSON(1974) the pressure intensity is essentially influenced by individual posture (change between on-load and off-load of the spine); influx of liquid into the disk tissue can only be traced up to a 70 kp interdiscal pressure.
Thus, aging of the intervertebral disk is closely linked to its loss of liquid. According to Smith, there are more modifications: in the third decade of a lifetime, there is a fibrous modification of the disk tissue taking place which does however not mean the loss of elasticity. In the fourth

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decade there is a fibrous modification combined with the loss of elasticity, and in the fifties there is a formation of fibrous connecting tissue clusters and first signs of degeneration are becoming evident.
Each degeneration of intervertebral disk tissue is resulting in changing biomechanical qualities and thus in INSTABILITY. Along with degeneration of the intervertebral disks, the adjacent vertebrae plates are damaged irreversibly and the biomechnaical balance of the "link chain: vertebral column" is severely disturbed, particularly the associated pair of vertebral arch joints.

2. Load Tolerance of the Intervertebral Disk

Sound intervertebral disks support much higher mechanical loads than the adjoining vertebrae. According to SONADA(1962,) at the lumbar spine area load limits of 255 kg/cm2 were calculated for vertebrae and 460 kg/cm2 for the intervertebral disks when determining the limits for rupture under longitudinal strains.

When investigating axial loads, the author of the present article ascertained a breaking load of 730 kg for lumbar vertebrae and 1500 kg for the intervertebral disk. Moreover, ROAF(1960) was able to prove that the ligament has capacity to absorb high energy strains. In the presence of exaggerated strain, i.e. excessive traction or bending of the vertebral column, there might rather occur a compression fracture of vertebrae than ligament rupture. Only when rotation was added, the ligament structures burst which led to dislocation fractures. Considering these findings, isolated traumatism of the sound intervertebral disk seems unlikely to occur without simultaneous injury of the bone.

Apart from nervous and psychical strains, aircraft pilots are moreover exposed to high strains upon the spine and the intervertebral disks by:
- acceleration forces in diverse directions
- escape by ejection seat
- exposure to vibrations in seated position of the body
- immobility
- unadequate and forced unnatural postures of the body over long periods of time
- additional loads upon head and cervical segments exercised by a 4 kg helmet
- combined loads such as during air combat and air space observation when high acceleration forces are coming into effect.

We attribute special importance to the high acceleration forces (g-forces) on the cervical spine and to the vibration strains exercised upon the whole body of helicopter pilots who remain in unadequate and forced unnatural postures.
As the above-mentioned load limits apply to a sound intervertebral disk, the load tolerance of an affected disk (prolapse) is considerably reduced.

3. Clinical Practice and Diagnosis of Intervertebral Disk Lesion

According to BRÜGGER(1960), intervertebral disk prolapse occurs in the following segments of the spine:

- lumbar:	L4/5 and L5/S1	:	3904
	L3/4	:	380
	L2/3	:	50
	L1/2	:	15
cervical:	C5/6 and C6/7	:	40, each
	C4/5	:	10
thoracal:	D11/12	:	9

Evidently the lumbo-sacral area is affected in the first place.

Considering clinical and neurological diagnosis we distinguish between: local cervical or lumbar syndrome, radicular peripherical pain syndromes, radicular symptoms with impairment of nervous functions as referred to motion and sensitivity, as well as deficient reflexes and spinal symptoms. Moreover, there could be observed cerebral, vascular, pseudoradicular complexes as well as mixtures of the symptoms as mentioned above.
Here we use the characteristic muscular diagnosis procedure, dynamometer control according to SCHEID or JANDA and the well known sensibility schemes in their modified version as described by MUMMENTHALER and SCHIAK.

Apart from anamnesis and clinical examination we dispose nowadays of varied figurative diagnosis procedures. On principle, however, one has to keep in mind that radiological findings cannot be considered to be absolutely reliable. Their real clinical importance only becomes evident when anamnesis, clinical examinations in the field of neurology or neuro-physiological tests have been carried through. We propose to make a diagnosis step by step, as follows:
- regular X-ray pictures of the column segment in question should be made in a-p and in lateral projection,

- x-ray pictures facultatively taken in inclined position,
- x-ray-pictures of the spine taken under working conditions in forward, backward and sideway inclination and in rotation,
- conventional tomography to be carried through in rare cases,
- myelography, to be performed in rare cases,
- computed tomography,
- CT-myelography,
- MRT - magnetic resonance tomography.

The methods to be applied depend upon clinical findings, treatment as initiated and above all , when surgery is deemed necessary.

Neurophysiological methods of examination are electro-encaphalography, evoked potentials, electro-myelography, electro-neurography, and ultrasound-Doppler-sonography.

By means of discography, computed tomography and MRT, intervertebral disk prolapse can be classified;
interdiscal fissures (protrusion, degree I and II, protrusion with sub-ligamental sequesters), prolapse of the disk (connected or free sequester) - these items are important for the therapy to be applied and the prognoses for a successful treatment.

Diagnostical and therapeutical problems may arise when additional degenerative alterations of the motion system occur such as:
Spondylarthrosis,unco-vertebralarthrosis, osteochondrosis, ligamental spondylosis, inflammations of the peripherical nerve root.

4. Therapy of Intervertebral Disk Lesions
In case of a diagnosis of cervical or lumbar intervertebral disk prolapse. independent of the distinctiveness of clinical symptoms, the respective pilot is not apt for military flying duties for the next 6 months. The adequate conventional or operative therapy will be initiated with stationary hospital treatment or on an outpatient's basis.

4.1. Conservative Therapy Measures.

According to KRÄMER (1986) approximately 98% of intervertebral disk prolapses are treated by conservative means. In the acute phase, the following measures are applied, such as relieving positioning (in a benched bed, for example, for painfree rest, or extensions), immobilisation by means of a plastic collar or corset for redressement and relief; drug therapy for analgesic purposes, myorelaxation and detumescence; and electrotherapy. Afterwards, therapeutical measures are administered for rehabilitation of muscular and nervous functions. Shortened sets of muscles are extended, weakened sets of muscles will be rebuilt, functional disturbances will be treated manually. In a special gymnastics' program, the correct posture for an ideal vertebral column will be taught("Rückenschule").

4.2. Surgery

Before proceding to intervertebral disk surgery, the operating surgeon should answer the following questions to himself (according to HEDTMANN 1988):

1.Is there an unambiguous pathoanatomical cause for root compression?
2. Are there any further compression factors, like a narrow spinal canal or recess?
3. What will be the consequences upon the segmental stability when further decompression has been realised as planned ?
4. Would this case of prolapse not rather require a less invasive therapy, like percutaneous discotomy?
5. Which would be the best way to minimize post-operative adhesions?
6. Are there tangible reasons to expect that surgery will lead to a more favourable course than the conservative therapy; were all adequate conservative measures exhausted?
7. Do we find any psychogenic factors apart from the organic components?
8. Are individual pain factors of the overall symptoms partly clarified and can surgery bring about a change for the better?

If there remain certain doubts as far as the indication is concerned and if the case is not urgent, surgery should not be performed.
In Berlin, 1909, the team KRAUSE/OPPENHEIM carried out the first intervertebral disk operation , in 1929 ALAJOUNINE performed the same operation in France and in the same year, DANDY untertook it for the first time in the USA. In spite of lengthy experience in this field, indication and extent of intervertebral disk surgery are disputed.

Advancing or primarily functional paresis and cauda-syndrome are absolute indications for discotomy. As relative indications we consider radicular lumbar syndrome, six weeks' competent conservative orthopedic treatment, positive correlating CT or MRT, free or sub-ligamental sequester, combined discogenic-osseous compression of the nervous roots and the patient' suffering as well as non-existent or insignificant pareses.
The following types of surgery are feasible:

4.2.1. Conventional discotomy

According to KRÄMER (1986) conventional discotomy carried out in micro-technique should be preferred considering the better results achieved by it. Standardized procedure is interlaminar windowing (flavectomy) with sequester removal and ID ectomy.In the case of dislocated sequesters, hemi-laminectomy is indicated, for laminectomy to be carried out on a routine basis responsiblity cannot be taken considering postoperative adhesions and the loss of stability (WHITE/PANJABI 1978);(GRACOVETSKI(1987). The results of conventional ID surgery technique vary between 77% related to 1500 (according to (ROTHMANN/SIMEONE 1982) and 91% related to 1550 surgeries (according to SCHMITT 1984).The success rate of micro-surgery of the intervertebral disk varies between 91% and 96% (GOALD 1978; WILLIAMS 1978; BINGAS 1984; EBELING 1984).

4.2.2. Percutaneous nucleotomy

Among different types of therapy for lumbal intervertebral disk prolapse, percutaneous nucleotomy represents the less intensive surgical procedure. We distinguish between non-automated (NAPLD-method) and automated (APLD) percutaneous discotomy. In 1974, HOPPENFELD carried out this type of surgery applying stab incision under local anaesthesia with the intention to cut short hsopitalisation. In 1975, HIJIKATA and assistants were the first to introduce a complete series of surgical instruments for percutaneous nucleotomy and to formulate the objective for the surgery which is intradiscal decompression with reduction of intradiscal pressure by removing nucleus material. HULT(1951) and HIJIKATA (1989) additionally point out to the importance of anulus windowing. Apart from the degree of intervertebral disk prolapse the amount of tissue removal seems to be of prognostic importance for successful surgery. HIJIKATA (1989) and GRAHAM(1989) both indicate 1.5 g as being the ideal quantity, while quantification proves to be difficult. In a twelve years' follow-up study HIJIKATA (1989) was able to prove a 72% success. Free sequesters as well as sub-ligamental sequesters are to be considered as contraindicative for percutaneous discotomy.

4.2.3. Chemonucleolysis

Chemonucleolysis is the non-surgical enzymatic removal of material of the nucelus pulposus. In 1963, LEYMANN/SMITH performed papain injection in the intervertebral disk for the first time and reports good results in 86% of the cases.
The first experiments examining chemonucleolysis on the basis of collagenase were carried through by SUSSMANN (1968) and SUSSMANN MANN (1969). Applying this method it is important to select the appropriate patient and to choose low-dose-chymopapain injection in order to minimize complicatons. A total success rate of 70 to 75% is stated.

4.2.4. Surgery of Cervical Intervertebral Disk Prolapse

Surgery of cervical intervertebral disk prolapse is now separatelytaken into consideration. Ventral procedure is prevalescent in its general importance as well as in frequency, methods are defined by CLOWARD (1958) and SMITH/ROBINSON (1958). As a rule the extraction of the intervertebral disk is combined with fusion of the cervical corpus vertebrae by ventral surgery. If, due to clinical and radiological findings we face the so-called hard-disc-conditioned pain by compression of the nervous roots, unco-foraminotomy should be carried through additionally, as described by LANG/KIHR (1979). Surgery of chronical cervical myelopathy in the case of multiple intervertebral disk protrusions is carried through dorsally (by means of laminectomy). For maintenance of a stable cervical spine the fusion of the motion segment is essential. In the first place allogeneous osseous pins taken from the crest of ilium are applied, less frequently homologeneous osseous pins, "Kieler Knochen" (bone chips of animals), bone cement, Palacos or Sulfix (ROOSEN 1979). As degenerative diseases of the spine are chronic it is essential to maintain the correct postoperative care for a sufficiently long period. This applies to the conservative measures as well as to the phases following surgery. The" ten rules of the Rückenschule"(special gymnastics program to train correct posture of the spine) according to KRÄMER have proved to be very helpful for social and professional rehabilitation as well as physiotherapeutical measures.

4.3. Complications And Failures of Intervertebral Disk Surgery

Most frequent complications are mere injuries of the dura which occur mostly with adherent prolapses and with repeated discotomies. As for exclusively microsurgical series of operations (GOALD 1978; WILLIAMS 1978) and with reference to percutaneous discotomies no dura injuries could be observed so far. As a rule, dura unjuries may be covered by sutura without any consequences or, in the case of damages, by lyophilized dura or by free plastic surgery using fatty flaps. Less frequently occur complications in the sense of nerve lesions which, in most cases, are caused by high tension on the nerve root (III 1983:0.8); (NELSON 1982: 0.8%) and vascular lesions. According to NELSON (1982) we find postoperative infections in 2.5% of the cases, according to LINDHOLM/PYLKKANEN (1982)in 0.75% of the cases. According to GOALD (1978) and WILLIAMS (1978) in series of micro-surgeries there were no postoperative disk inflammations. SUEZAWA/SCHREIBER (1988) and MAYER/BOCK (1988) discovered a higher percentage of postoperative infections with percutaneous discotomy as compared to conventional discotomy.
Failures of intervertebral disk operations are due to:

- erroneous identification of the segment to undergo surgery
- non-identified free sequester
- minimal osseous decompression
- postoperative iatrogenic instability
- persistent anulus bulging
- recurrent prolapse
- epidural fibrosis
- segmental instability
- facet syndrome with minimum segmental instability
- arachnitis.

By origin, the post-discotomy-syndrome (PDS)in the narrow sense is a combination of epidural fibrosis, subdural adhesive arachnitis and segmental instability, eventually combined with persistent anulus bulging and recurrent prolapse. Further revisional surgeries are rarely successful. At the presence of epidural fibrosis and instability, patients are very responsive to flexion therapy and fusion surgery. Course and prognosis of arachnitis are hardly to be judged. In summary, adequate diagnosis is imperative as well as surgery techniques which do not put too much strain upon the patient, and an adequate postoperative care.

5. Judgement of Ability for Military Flying Duties

For the assessment of the ability for military flying duties, considering the high strains upon the spine and the intervertebral disks due to flying in a jet aircraft with ejection seat and high g-accelerations in a seated position,the answers to the following questions is of vital importance:

1. Localisation of the intervertebral disk lesion (lumbal, cervical or thoracal position);
2. Extent of the intervertebral disk lesion (protrusion, prolapse, free sequester);
3. ID lesion in one or more segments;
4. Is there a narrow spinal canal or a narrow recessus, additionally;
5. Result of an adequate conservative therapy or surgical intervention;
6. were surgeries carried through for further osseous decompression or fusion;
7. which are the specific aircraft strains;

8. How is muscular stability of the trunk and of the cervical muscles achieved;
9. How are comparable strains tolerated after surgery (like sports activities, virtual strain test under the observation of the flight surgeon and of the weapon system operator;

Six months after the first diagnosis, the ability for military flying duties is assessed considering the clinical and radiological diagnoses as well as after an adequate conventional or surgical treatment.

5.1. Cervical ID prolapse

At the given diagnosis of cervical ID prolapse, we consider that there is no ability for military flying duties neither on a jet aircraft with an ejection seat nor on a helicopter with high vibration strains, independent of the results of an eventual surgery or any conservative treatment applied. Our decision is based upon the extreme strains upon cervical segments which might occur by way of leverage coming about by high acceleration forces in various directions or by additional strains of the cervical vertebral column due to the helmet which has a weight of approx. 4 kg weight, or by extreme strains in air combat and during air o[illegible]ation, when the pilot has to apply high energy forces against centrifugal forces. As the occurrance of an isolated traumatic ID prolapse does not seem plausible, we have to consider a latent ID disease due to a genetically determined quality of ID tissue, even if we find in the CT or MRI only a mono-segmental ID lesion.
We also know that after fusion surgery, the adjacent motion segments are exposed to increased strains. Functional disturbances and premature signs of wear of all components of the motion segment might appear more frequently. Another aspect is fixation of the verteral column on the seat of the pilot. Thoracal and iliacal vertebral column are stabilized by the seat and the belt system, the cervical part of the spine is just supported dorsally by the headrest.
Muscular stabilization of the cervical segments by the neck muscles is more unfavourable by anatomic standards as compared to muscular stabilisation of the iliacal vertebral column by the trunk muscles.
After successful treatment and rehabilitation conversion training (for example on a C160 or B707 aircraft) may be initiated.

5.2. Lumbar Intervertebral Disk Prolapse

After successful conservative or surgical treatment of lumbar ID prolapse, that means complete cure or minimal residues of irritated root syndrome, sufficient spine mobility, freedom from pain even under strains, as well as a good stabilisation of the lumbar vertebral column by strengthened trunk muscles, we consider the ability for military flying duties to be restored after six months' break. In the beginning, clinical examinations should be realized by the flight surgeon on a regular basis. In the case of recurrent complaints ability for military flying duties cannot be recognized. Moreover, in the case of lumbar intervertebral disk prolapses and their surgical treatment with further osseous decompression(p.ex. laminectomy) we do not consider that there is sufficient ability for military flying duties .
Our favorable decisions depend upon a good muscular stabilisation of the lumbar vertebral column by optimally trained trunk muscles, fixation of the trunk on the seat and by means of the belt system thus achieving a minimum of strain exercised by leverage and rotation. In order to minimi[illegible] ID affections originated by vibration strains upon the whole body, we recommend reduction of flying hours per day and year.

6. Summary

The intervertebral disk, central element of the motion segment, may be exposed to high strains which occur when piloting a jet aircraft or a helicopter. Isolated traumatic ID lesions due to flying strains do probably not come into existence neither ID degeneration according to our actual findings and knowledge of the matter. When there is an accurate diagnosis as to ID prolapse considering clinical and radiological findings, ability for military flying duties is accepted for the next six months. Adequate therapy, either by conservative or surgical treatment, is to be initiated. In the case of cervical ID prolapse however, we do not recognize ability for military flying duties for pilots of jet aircraft seated on an ejection seat and for helicopter pilots, even after good results of treatment. After lumbar ID prolapse and good results of treatment we consider the ability for military flying duties as being restored. Thereafter and when the first flying strains set in, the responsible flight surgeon should examine the pilot regularly, at least in the beginning.

Spinal Nerve Syndromes: The Need to Confirm the Diagnosis with Neurophysiological Examinations

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1. Summary:

Because even the normally healthy pilots suffer from the usual aging and degeneration of the spine, sudden g-stress may lead to compressions of spinal nerves if degenerated intervertebral discs protrude into the intraspinal space.
To avoid risks to general flight safety as well as to the pilot's health, back pain and sciadic syndromes have to be evaluated aeromedically.
The common methods to investigate the cause of spinal-nerve affections can be divided into three steps

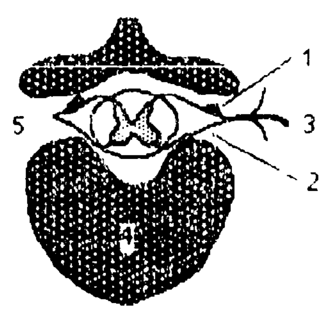
First the intensified interrogation and clinical examination of the pilot, which usually leads to the rough specification of the location of the lesion as well as a first hypothesis of the cause (e.g.: A probably traumatic lesion of the left first thoracal nerve)
Second usually come radiological methods such as X-ray of the spine and, more promising, a X-ray computer tomography (CT) and in difficult cases magnetic resonance imaging (MRI), which can differentiate between tumors and protusions of intervertebral discs
In the third step the extent of the damage is evaluated by neurophysiological methods. From the viewpoint of aeromedical decision making this step is the most critical
Of the suitable methods there are the following used in the GAF Institute of Aviation Medicine (GAF IAM)
Electromyography: Fast, rather accurate and reliable, though it covers only the motorical part of the nerve root.
Neurography: F-wave measurements can detect lesions in the motorical part of the nerve root
Somatosensory Evoked Potentials (SEP): Though time-consuming and demanding they offer the only way to measure sensory deficits
Magnetically Evoked Potentials: Not available
To illustrate the decision making process, examples are demonstrated

2. Abbreviations and definitions:

Spinal nerves will be abbreviated. The first cervical nerve will be called „C1", the third thoracal nerve will be called „Th 3", the fifth lumbal nerve will be called „L5", and the first sacral „S1".
The intervertebral discs will be named according to the adjoining vertebrae, e.g. „a protrusion of the disc L5/S1".
A protrusion of an intervertebral disc is a minor bulging compared to a prolaps, where the ligamental structures are ruptured and there may be an dislocated piece of the disc causing symptoms.
A nerve irritation causes pain or paraesthesia, whereas a nerve compression will cause sensory or motorical deficits (i.e. anaesthesia or paresis)

3. Anatomy and Pathology:

The Central nervous System consists of both brain and the spinal cord.
The Peripheral nerve system starts with the nerveroots of the cranial or spinal nerves. The spinal nerves leave the spine through foramina intervertebralia
Figure No. 1



1 Posterior root with spinal ganglion (sensory)
2 Anterior root (motorical)
3 Spinal nerve
4 Vertebra (thoracal)
5 Intervertebral hole (foramen intervertebrale)

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Because of the anatomical dimensions (see Figure No. 1), the most critical stations for possible lesions of the nerve are the intervertebral holes. If one would draw the cut through the human spine just a little bit higher or lower than in Figure No. 1 one can see the intervertebral disc, as shown in Figure No. 2.

In it the most common causes of spinal nerve irritation are demonstrated. On the left one can see a compression of a nerve root, further complicated by reactive inflammatory swelling.

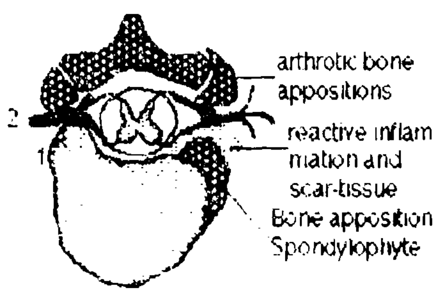
The cause of the nerve irritation on the right side has evolved far slower and stems from bone appositions and scar tissue. The onset of symptoms is slower than in a case of a protrusion of the intervertebral disc and the illness affects normally several segments of the spine.

While degenerative alterations of the bone structure are the most common cause of nerve irritation in the cervical part of the spine, intervertebral disc protrusions or prolapses are the most important factors in lumbosacral nerve syndromes (Hopf et al. 1993)

Figure No. 2:

1: Prolaps of the intervertebral disc, leading to

2: Reactive swelling of the nerve root



4. Symptoms

To understand the syndromes of spinal nerve affections one has to take into account the segmental structure of the nervous system. With a rather great interpersonal accuracy a certain nerve root has the same motorical and sensory functions in all individuals.

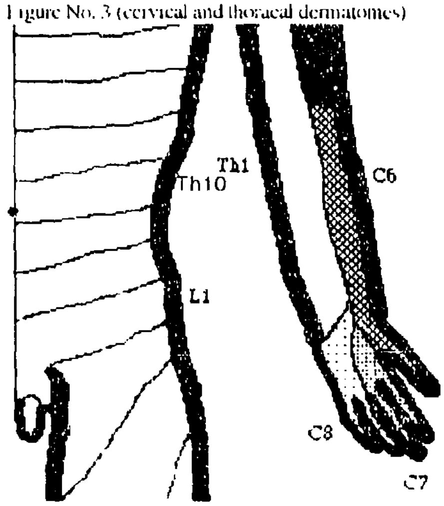
The localisation of the symptoms gives first hints to the nerve roots, whereas the kind of symptoms may reveal whether there is just a irritation of the nerve or if there is a compression with a resulting loss of function of, say, the sensory part of the nerve.

The most important symptoms are:

Generalised pain: Small irritations of several nerve roots will lead to higher muscular tension, leading to the typical back-pain without any segmental orientation.

Segmental pain or paraesthesia: Pain according to the anatomy of one nerve- root. This is caused by the irritation of the nerveroot and leads typically to a „road of pain" according to the limits of the dermatome.

Figure No. 3 (cervical and thoracal dermatomes)



Anaesthesia: Due to the compression of the sensory fibres of the nerve root, no perception of pain is possible in the dermatome.

Weakness: Also called algogenic paresis. The weakness tends to minimize painful movements and doesn't follow segmental rules.

Paresis: A real paresis stems from the compression of the anterior nerve root. Most muscles are innervated by several nerve roots but certain muscles may be partly or completely paralysed by the loss of innervation from a single nerve root.

Other symptoms: The [illegible]pression of the cervical myelon itself (e.g. by a large sequestrating prolapse) may lead to a Brown Sequard Syndrome with paraparesis of the legs.

Typical syndromes may be:

1. A recurring pain of neck and shoulders may be caused by degenerations of the cervical spine with unspecific irritation of several nerve roots, resulting in painful contractions of the paravertebral muscles.

2. A recurring pain and paraesthesia of parts of the right shoulder and arm, forming a road that leads to the middle finger. This may be caused by a irritation of the right seventh cervical nerve root by a narrowed intervertebral hole.

3. Pain, followed several days later by a „achieving"

anaesthesia of the exterior side of the right leg, forming a road to the great toe. This is probably due to an irritation and swelling, resulting in compression and loss of function of the sensory part of the root L5 by a lateral prolaps of the intervertebral disc L5/S1.
4:Pain and weakness in the left leg. The most painful radiations of pain lead to the fifth toe, even with powerful medication there is an unability to stand on toetips. Later there occurs a sudden onset of incontinence and anaesthesia of the genitoanal region.
These symptoms may be caused by a large and sequestrating mediolateral prolaps of the disc L5/S1 that first compresses the left root S1, and later, after a little dislocation additionally compresses the remaining sacral nerves (Cauda equina).

5. Investigation

After the patient has presented several symptoms, a careful interrogation, followed by an examination has to take place.
The exact interrogation includes explicit questions concerning:

- Onset of symptoms (sudden under stress vs. gradually)
- Specificity of symptoms (pseudo- vs. segmental)
- Localisation
- Extent of root lesion (irritation vs. compression)
- Duration and changes of symptoms
- Other symptoms such as incontinence or impotence which may be thought embarrassing

The normal routine examination will be modified according the symptoms.

Table 1
The neurological routine-examination of the pat[illegible]
(Duration of interview and examination without disturbances or pathological findings: 10-15 minutes)

- Coordination: Blind-walking-on-a-rope, Unterberger's treading-examination, Finger-nose and Knee-heel-trial, diadochokinesis
- Muscle tonicity, force and trophicity: Abduction of the arms, flexion and extension of the elbows, hand-gripping and extension, straddling of the fingers, flexion and extension of hip and knee, ability to stand on heel and toes
- The cranial nerves: Eye-and pupillar-movement (all directions, accomodation- and light-reflex), corneal-reflex, sensibility of the face, tongue movements, retching-reflex, m.masseter, hearing, force of the m.sternocleidomastoideus
- The reflexes: biceps- and triceps brachii-tendon reflex, Troemner's reflex, abdominal-wall-reflex, patellar- and achilles-tendon-reflex, Babinsky's-reflex
- Sensory-function: touch and vibration
- Hidden paresis: blind elevation of arms, later of legs
- Arteriosclerosis: Auscultation of subclavian and carotid arteries

This kind of routine examination is implemented with other standard techniques such as Cremaster reflex or investigation of the perception of pain or temperature regarding to the symptoms.
After this interrogation and examination one is normally able to generate a hypothesis regarding the cause of the symptoms, so that in the next step one can select the apropriate radiologic method (e.g. conventional X-ray of the cervical spine in four planes or CAT-scan from L3/4 to L5/S1). Since these methods are available in our GAF [illegible], they can be done without loss of time.
To evaluate the results from the radiological department, one needs information concerning the function of the affected nerve root.
One part of this information can be drawn from the interrogation and examination, yet this information may be not very reliable (see chapter evaluation).
The neurophysiological methods available (Widder 1994) are listed in Table 2.

Table 2
The neurophysiological investigation

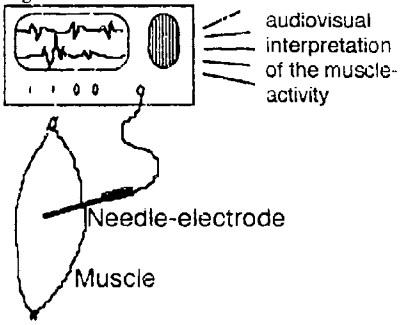
- Myography: It can very reliably detect lesions of the anterior root (motorical part of the nerve-root). Quick and sensitive yet invasive and painful.
- Neurography: Nerve-conduction-measurements can detect only peripheral lesions, but the measurement of F-waves can give informations about the anterior root. The H-reflex can yield informations about lesions of both the anterior and the posterior root S1. Quick and noninvasive.
- Somatosensory Evoked Potentials (SSEP): The only way to get a clue of the sensory system. Time consuming and artefact-prone.
- Magnetically evoked Potentials (MEP): Not yet available at the GAF (A).

The methods in use at the [illegible] explained. Since myography and [illegible] methods are older and generally [illegible] be explained in less detail.

Myography

The aim of this investigation [illegible] and myography [illegible]
The method uses [illegible] activity in various areas of the muscle [illegible]
[illegible] signs of a new or continuing [illegible] method it is possible to distinguish [illegible] weakness and actual paresis [illegible] thought over [illegible] potentials are seen as signs [illegible]
The method has [illegible] yields very reliable results.
[illegible] Figure [illegible]

Figure No.4: EMG



Neurography:

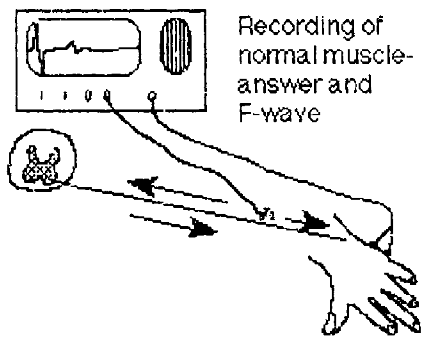
The routine nerve-velocity-measurements offer no insight into nerve-root processes since they record the nerve-function of the distal part of the nerve.

With F-wave-measurements however, you are able to assess the function of the whole peripheral nerve, including the nerve-root.

While eliciting normal motorical nerve-responses, one can record somewhat irregularly late responses that are caused by retrograde excitation of the motorical fibres with a following normal excitation and (weak) motorical answer (see Figure No.5).

By comparing the sides one can normally detect significant slowing of the F-wave, if the anterior root is damaged.

Figure no.5: F-wave



H-reflex:

With a similar technique as in the F-wave-measurements one can obtain H-reflex-answers from the m.triceps surae.

The main difference lies in the fact that the H-reflex-response travels first in the sensory fibres and is switched to the motorical fibres in the spinal segment S1, so that one can detect lesions in both the motorical and the sensory parts of nerve-root S1. The obvious limitations lie in the fact that one can only assess the root S1.

While the methods mentioned above are easily administered and interpreted they deal mostly with the motor-root dysfunction.

Somatosensible Evoked Potentials (SSEP):

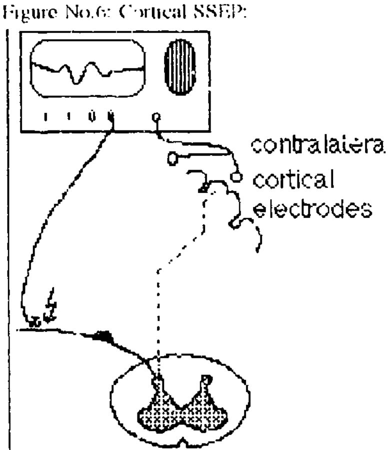
Since the most common clinical deficit is sensory (Chiappa, 1990), and sensory reports tend to be inaccurate (Date et al, 1988) the need arises to evaluate objectively.

Especially with pilots the sensory reports tend to be inaccurate if the pilot dissimulates the symptoms for fear of loosing his licence.

The only way to measure the function of the sensory parts of an irritated nerve root (Stohr et al, 1989) lies with the method of SSEP.

With this method (Dawson, 1947a) one tries to measure the cortical potentials that are the result of stimulation of nerves or skin and can be recorded contralaterally to the stimulation over the primary sensory areas of the brain (Figure No.6). There were methods evolved to measure the evoked potentials over the spine also.

Figure No.6: Cortical SSEP:



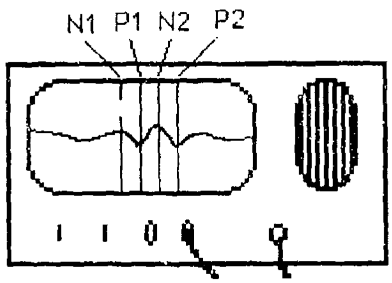
modified after Maurer et al,1990

With cortical SSEP one has the limitation of testing the whole somatosensory system, so more differentiated results can be obtained by the method of fractioned SSEP where a combination of spinal and cortical SSEP allows precisely to locate the region of the lesion.

Normally the stimulation of the sensory fibres is done directly by stimulating a nerve-trunk. Regarding the investigation of nerve-root-syndromes this has the drawback of stimulating several nerve-roots at once. Hence the concept of dermatomal stimulation allows

to stimulate ideally just one nerve-root (see also Figure No.3).
Having stimulated in the area of the desired dermatome one has to average 250 times to eliminate stochastic disturbances.
Then the results have to be measured (see Figure No.7). starting with a negative wave N1 (conventionally pointing up), followed by a positive P1 after which come again a negative N2 then a P2.
Latencies as well as amplitudes are measured.

Figure No.7: SSEP-Measurement:



The results of the measurement are evaluated
- observed latencies against normative-values (Jörg and Hielscher, 1984 or Chiappa, 1990).
-side-differences of latencies or side-differences of amplitudes (Chiappa, 1990, Widder, 1994).

By some authors the sensitivity of the dermatomal SSEP- investigation has been compared with that of myelography (Katifi and Sedgwick, 1987) or of EMG (Tans and Vredeveld, 1992), most want to add it as a useful method to their electrophysiologic battery (Saal et al, 1992, Walk et al, 1992) and some think that they are not useful (Schmid et al, 1988).

Theoretically it is possible to investigate fully a sensory lesion with help of the fractioned SSEP with dermatomal stimulation but the method has a certain first drawback because it is very time-consuming.
An investigation of just two segments (cortical measurement) needs aproximately one hour. so we decided not to do fractioned but only cortical SSEP.
The second drawback lies in the fact that the method is difficult to perform and rather artefact-prone. In volunteers there are much less artefacts than in tense pilots who suspect some malignancy of the physicians.

Since the dermatomal SSEP offer the only insight into the sensory-root function, we decided to adopt the method of cortical SSEP. The fractioned technique would have made things further complicated, while lesions of the distal nerve are generally easily accessible to neurography.
To avoid controlling for body height and temperature we generally use only the side differences.
Side-differences in latency of more than 3 msec are seen as pathological as well as loss of curve or more than 66% loss of amplitude.

6. Evaluation:

After the investigation detailed in chapter 5 the accumulated facts and reports have to be evaluated.
General considerations:
The first informations are given by the pilot himself. The physician in a normal clinical setting can rely heavily on the voluntary reports of the patient. The informations given by the pilot have to be viewed carefully, because many pilots tend to dissimulate in order to maintain their licence. Sometimes seemingly irrational fear of getting grounded gets in the way of a normal exchange of information. Since the physician has to keep in mind both the flight-security and the pilot's health he is not always able to decide in acordance with the pilot's declared intention- a fact the pilots are aware of.
So in general the pilot's reports concerning the symptoms may give valuable information, but may in some cases grossly understate the extent of the illness.

The clinical examination relies on the pilots reports so far as sensory deficits are concerned, so that information concerning the sensory system tends to underestimate the lesion.
Pareses on the other hand will be easily investigated- more with the danger of overestimation because of algogenic components (especially if the pilot failed to report the pain).

The radiological data will state objectively the extent of the morphological lesion but will of course leave open the question of the clinical relevance of the results. In some cases severe degenerations of the spine do not cause any symptoms while everyone of us knows some cases in which it was difficult to accept minor radiological findings as the cause of disabling symptoms.
As stated previously even these objective radiological data have to be evaluated concerning their significance to the subject's symptoms.

Helpful at evaluating the significance of radiological findings as well as with assessing the extent of damage to the sensory or motorical parts of the affected nerve-roots are the neurophysiological methods described in chapter 5.
With myography one can investigate the motorical

lesion and can discern weaknes from paresis. As well one can get reliable information of the chronicity of the process. Some of these informations can be obtained by F-wave recording as well.
With the H-reflex-measurement one can investigate the complete nerve-root S1.
With the method of dermatomal stimulated cortical SSEP one can investigate the sensory roots. The results, however tend to show a rather optimistic picture of the lesion, since the information of the remaining intact fibres can be amplified by the CNS so that the cortical response may appear rather normal. An intact SSEP-response however shows a good prognosis (Chiappa, 1990) of the nerve-root lesion and can insofar be used to support an only temporarily grounding of a pilot with a nerve-compression-syndrome.

Special considerations:
Because the aeromedical decision-making is influenced by the aim to keep both the pilot's health and the flight-security at the highest possible level, two areas have to be considered:

Actual disabilities:
In order to maintain flight-security, the pilot has to be able to accommodate the needs of aircraft-operation.
Therefore the pilot must not have any paresis. He must be able to move freely with sufficient speed. His sensory system must be intact so that he can operate sticks and switches or pedals without having to look at them.
His spine must be stable enough to endure the sudden onset of g-force that occurs during military aircraft-operaton.

Prognosis/ the pilot s health:
The normal course of the illness has to be taken into account together with the question wether the pilot's duty will accelerate the degeneration. (e.g.: The need to carry a helmet, often with night-vision-goggles, together with the typical vibration and g-stress may accelerate the degeneration of a cervical spine that is already symptomatic)

Guidelines to evaluation at the GAF IAM:
There are several guidelines to evaluate spinal nerve syndromes.
-Asymptomatic lumbar intervertebral-disc herniations will be regarded as not very dangerous.
-Lumbar intervertebral-disc protrusions profit from intensive physiotherapy (as do all forms of spinal nerve-syndromes) and are regarded as not very dangerous.
-A lumbar intervertebral-disc prolaps has to be investigated carefully if symptoms are reported. Usually the pilot will be grounded for six months during wich he will undergo a vigorous regime of first stationary, later ambulant physiotherapy. Since the pilots are generally highly motivated to cooperate with the physiotherapists the results and prognosis are very good (dramaticaly different from the normal patients seen in a hospital).
-Cervical vertebral degeneration will normally devellop slowly. The pilots sometimes use the time to find new perspectives outside the aircraft and reach the conclusion that they simply are no longer fit to fly.
If however there is little pain the evaluation has to take into account the possible sensory deficits or pareses.
-Cervical disc-herniation is generally seen very critically. Since the cervical spine is much more instable and has less space to accomodate a prolaps or reactive tissue-swelling, the danger of compression-syndromes up to a Brown-Séquard-syndrome have to be taken into account. This normally excludes further flying.

7. Examples:

All soldiers presented are white, male and have no important other symptoms or illnesses than the neurological ones stated briefly below in the cases.

7.1: A 45 years old lean right-handed pilot without any complains shows an unusual side-difference of the triceps brachii muscles: the left muscle appears to be atrophied, maximum force is much less than that of the right side even if one takes into account that the pilot is right-handed.
Because absolutely no symptoms are reported and the examinatoin yields no other symptoms the investigation directly starts with an myography of the triceps brachii muscle. The myography shows completely normal muscle-potentials from several parts of the muscle without any trace of spontaneous activity.
The atrophy and weaknes of course could be attributed to a compression of the left nerve-root C7, but would surely lead to signs of denervation in the myography.
Diagnosis: Severe lack of training .
Recomendation: Build-up of the muscle with sports like swimming.

7.2: A 48 years old pilot complains of recurring lumbalgia and cervicalgia after longer flight-missions. Upon more detailed questioning he produces symptoms of an irritation of the roots C6 and 7 of the right side, while underlining his will to cooperate with the aeromedical institute. After questions concerning previous radiological examinations (no specific done yet) he gets annoyed at our distrust .
The clinical examination reveals additional signs of a

complete compression of the right roots C6+7 : Paresis and atrophy of the right biceps and triceps brachii muscles. Fasciculations are observed, hinting at activity of the denervational process.
The pareses are denied by the increasingly distressed pilot who seems insulted by our proposal of a CAT-scan, but has to comply.
The CAT-scan reveals corresponding massive degenerations of the cervical spine with an older mostly calcified process (perhaps an old herniation of an intervertebral disc) using up the intraspinal space, forming a compression of the myelon. The intervertebral holes are tightened by degenerative bone appositions.
Diagnosis: Compression-syndrome of the right nerve root C6+7 due to degenerative bone-alterations.
In this case no neurophysiological investigations are needed to ground the pilot.
Firstly it is not acceptable that a pilot does not observe important failures of his own system.
Secondly the manifest pareses of important muscles exclude flying.
Thirdly the visible compression of the cervical myelon may be compensated just now but it is possible that relatively minor changes of pressure cause a cessation of local blood-flow that may lead to lesions up to a full-blown Brown-Séquard syndrome.

7.3: A 34 years old jet-fighter backseater (weapon-systems-officer) complains of seldomly and only under sudden and unexpected g-stress occuring paraesthesia of the left dermatome C6 (see Figure No. 3).
The further interrogation reveals a spine-injury in 1988 that was evaluated as not relevant. The clinical examination is completely normal.
A MRI-tomography of the cervical spine reveals degenerations of the intervertebral discs C4/5 and C5/6 without protrusions and a left-mediolateral protrusion of the disc C7/Th1.
The neurophysiological investigation includes dermatomal SEP of the dermatomes C6-8 that show completely normal latencies.
Diagnosis: Irritation of the left root C6.
Evaluation: Even though it is possible but improbable that a 'prefixation' (Owen et al. 1993) of the root C8 has taken place so that the protrusion of the intervertebral disc C7/Th1 will irritate the root C8 which in turn would then innervate an area commonly innervated by root C6, the findings of completely normal SEP make it probable that the MRI-finding has no clinical relevance.
Since the protrusion of the intervertebral disc was asymptomatic, we saw no aeromedical relevance, either.

7.4: A 30 years old instructor complains of recurring sciadic symptoms (irritation of right root S1) and of thoracic pains since his test-bail-out with a too-powerful simulator 1988 that led to a compression-fracture of the thoracal vertebrae 4 and 5.
Further interrogation reveal no clear-cut nerve-root symptoms but pain and paraesthesia in the dermatomes Th4+5.
The performed CAT-scan offers no valuable information since only the bone was investigated.
The dermatomal SEP show normal latencies and amplitudes in the segments L5, S1 and Th3. The curves from Th4 and 5 are distorted with partly significant side-differences of the latencies.
These results can be brought into accordance with a posttraumatic nerve irritation and partly compression of the left root Th5, probably by scar tissue.
If the soldier were a pilot, the severity of the pain-syndrome would have to be taken into account in order to evaluate this spinal nerve syndrome.
The stability of the spine seems to be normal and a progression of the illness through normal duties seems improbable.

8. Conclusion:

Since objective data are necessary in the process of aeromedical evaluation of spinal nerve syndromes, it is proposed that a basic test-battery of neurophysiological inveтigations is available, including myography, neurography and somatosensible evoked potentials.

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THE AEROMEDICAL IMPLICATIONS OF SUPRAVENTRICULAR TACHYCARDIA

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1. INTRODUCTION

Supraventricular tachycardia (SVT) is uncommon in healthy screened populations and has an overall prevalence of 0.02% (1) and a maximal prevalence of 0.1% on routine screening electrocardiograms (2-8), 4.6% on Holter monitors (9-12) and approximately 0.6% on treadmills (13,14). A review of the clinical literature reveals that occupational and aeromedical risks for aviators with SVT remains inadequately addressed. Long term follow-up data in aviators with SVT is limited to a single small series by Matthewson and Varnam (4) who followed four aviators for 14 years and found no deaths or coronary events.

The Aeromedical Consultation Service (ACS) is a centralized United States Air Force (USAF) referral center which performs aeromedical evaluations in aviators to determine their fitness for flying. The ACS has evaluated aviators with SVT since 1955. In 1973, The ACS developed a protocol permitting resumption of flying duties in aviators with SVT; waivers were granted in selected low aeromedical risk cases. We have continued to provide clinical follow-up of aviators with SVT to insure that waivers for SVT are recommended only in low aeromedical risk cases.

Although uncommon, SVT can present suddenly with presyncope, syncope or sudden death with potentially catastrophic results during flying duties. Aviators with SVT were disqualified historically because of these risks. Medical standards must be conservative to insure that USAF aviators are free of such conditions. However, this conservative approach has disqualified many asymptomatic aviators who may have safely flown if data had been available demonstrating that certain subsets had an acceptably low aeromedical risk.

When evaluating an aviator with SVT, waiver authorities must determine the extent of aeromedical risk, the level of risk acceptable for continued flying duties and which waiver restrictions should be applied. This paper provides outcome data, acquired from aviators with various SVT presentation profiles, to assist in that risk stratification. With these data, a safe return to flying duties for those aviators with acceptably low levels of aeromedical risk can be achieved.

2. METHOD

All ACS charts with referral or incidental diagnoses of SVT between Apr 1955 and Dec 1991 were reviewed. We defined SVT as three or more consecutive nonventricular ectopic beats at a heart rate equal to or exceeding 100 beats/minute. We excluded aviators who had atrial fibrillation (AF), atrial flutter (AFL) or multiform atrial tachycardia (MAT) as the initial dysrhythmia. Follow-up was obtained from serial ACS evaluations and responses to a detailed questionnaire mailed to the aviator. All responses suggesting an abnormality were verified by a flight surgeon/cardiologist. When necessary a surviving spouse or relative provided information. Death certificate data provided supplemental information. All aviators considered for waiver completed an extensive evaluation that was based on current technology. The initial ACS evaluation included comprehensive flight medicine and internal medicine exams, screening ophthalmologic and audiologic exams, screening laboratory studies which included thyroid function testing and lipid values, chest and KUB X-rays, electrocardiography, treadmill, and spirometry. Over the 35 years ancillary tests were added as technology evolved to provide what ACS cardiologists considered to be optimal aeromedical and clinical testing for aviators with SVT. These tests included coronary artery fluoroscopy, Holter monitor testing, echocardiography, thallium scintigraphy and electrophysiologic studies to exclude previously unrecognized pre-excitation, disorders of the conduction system or characteristics of the induced SVT. Left-heart catheterizations were performed selectively in aviators with SVT to define coronary artery anatomy until 1986 when all aviators with diagnoses of SVT more than 35 years old were required to have this procedure. Aviators were excluded from flight duties if they had underlying heart disease such as coronary artery disease or valvular heart disease. Aviators with hemodynamically unstable SVT, frequently repetitive episodes of SVT or those requiring maintenance medications were not considered for waiver. Subsequent ACS evaluations were limited to internal medicine exams and noninvasive internal medicine testing.

Cardiovascular endpoints were defined as any medically significant events that were directly related to an episode of SVT. These included signs or symptoms of cardiac hypoperfusion such as sudden death, syncope, presyncopal symptoms of anginal chest pain due to SVT, unexplained dyspnea and signs or symptoms of cerebral hypoperfusion such as lightheadedness or visual changes such as tunneling of vision. For this discussion, hemodynamically stable SVT was any SVT that was symptom-free or that was associated with nondisabling symptoms such as palpitations. Sustained SVT was any SVT of ten or more minutes duration.

Data analysis was performed on a VAX® 6320 mainframe using a Smartstar® structured query language addressing a Sharebase® 700 relational database. Statistical analysis was performed using programs from the SAS (15) Institute on a VAX® 11/780 minicomputer. Relative risks were calculated using odds ratios.

3. RESULTS

3.1 ACS and Follow-up Data

A total of 957 ACS evaluations on 430 (428 men and 2 women) aviators with SVT diagnoses were reviewed. Electrocardiographic tracings were available for review in 397 aviators. The 33 tracings which were not available, had been previously reviewed and confirmed during prior ACS evaluations or at the aviator's base of origin. The mean age at the time of the index ACS evaluation for SVT was 40.3 ± 9.2 (men 40.3 ± 9.2 years and women 30.4 ± 7.2 years). A total of 274 (64%) aviators received only one ACS evaluation for the SVT. Questionnaires were completed in 427 (99%) aviators. Aviators with multiple ACS evaluations had a mean follow-up of 5.5 ± 4.1 (1SD) years, the median was 4.2 years and the range was one to 23 years. The mean follow-up, including questionnaire data, was 11.4 ± 9.0 years, the median was 7.9 years and the range was one to 35 years.

3.2 SVT Characteristics

The number of SVT runs for each aviator is given in Figure 1. There were 224 (52%) aviators who had a single run of SVT. The longest SVT duration for each aviator is given in Figure 2. Hemodynamically stable nonsustained SVT was present in 346 (80%) aviators; 84 (20%) had sustained SVT. These percentages include data from four aviators for whom no firm duration data exists. Review of the medical records and interviews with the aviators permitted us to place them in the hemodynamically stable nonsustained SVT group because their estimated SVT durations were less than five

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minutes. Figure 3 discloses the maximal heart rate of each aviator's fastest SVT. Seventy-one (16%) aviators had SVT runs that exceeded 200 beats/minute.

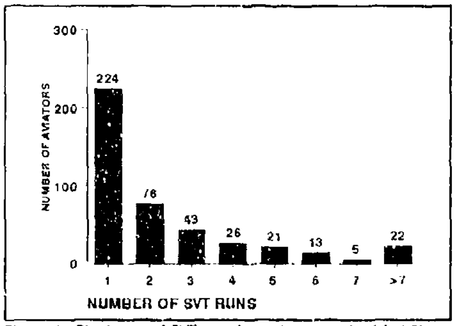

Figure 1 Distribution of SVT runs for each aviator. A total of 224 aviators had only one run of SVT.

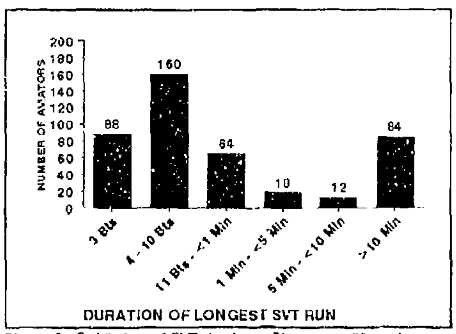

Figure 2 Distribution of SVT durations. There were 88 aviators whose longest SVT duration was 3 beats and 160 whose longest SVT duration was between 4-10 beats (Bts=beats, Min=minutes, N=4 with no data)

Aviators had one of four different SVT presentations during index ACS evaluations. The SVT presentation profiles were single or recurrent nonsustained episodes or single or recurrent sustained episodes. The aviator was placed into the appropriate group based first on the maximal SVT duration and second on whether the SVT was recurrent. The groupings for each aviator on the index ACS evaluation is given in Figure 4. Of the 392 aviators with hemodynamically stable SVT on the index ACS evaluation, 224 (57%) aviators had single nonsustained (SNS) SVT, 117 (30%) had recurrent nonsustained (RNS) SVT, 28 (7%) had sustained SVT and 23 (6%) had recurrent sustained SVT. Ten of the aviators with single nonsustained (SS) SVT and nine of the aviators with recurrent nonsustained (RS) SVT had other supraventricular tachydysrhythmias at the time of the initial ACS presentation. Of the 38 aviators who initially presented with unstable SVT, 1 had single nonsustained SVT, 4 had recurrent nonsustained SVT, 14 had single sustained SVT and 19 had recurrent sustained SVT. None of the 38 aviators initially presenting with unstable SVT had other forms of SVT such as AF, AFl or MAT (SVT + OTH).

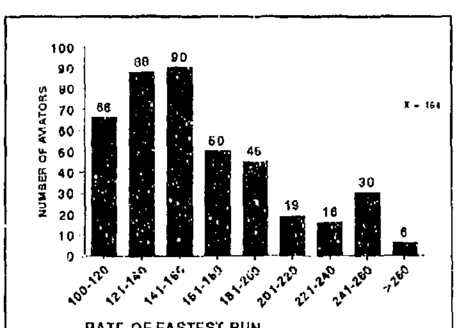

Figure 3 Distribution of maximal SVT heart rate for each aviator. There were 71 aviators whose maximal SVT heart rates were ≥ 200 beats/minute. (N=20 with no data)

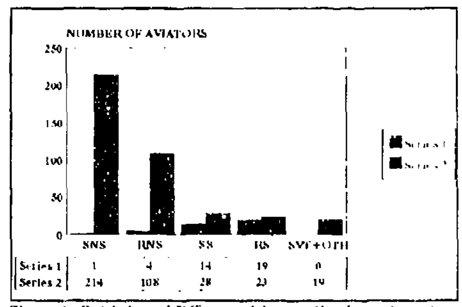

Figure 4 Distribution of SVT presentation profiles for each aviator. Series one is stable SVT and series two is unstable SVT

3.3 Endpoint Data

There were 25 (6%) deaths in the study group. Review of available medical records confirmed that SVT was not a cause or factor in any of these deaths. The mean age of death was 60.0 ± 11.3 years and the range was 39 to 75 years. There were 12 cardiac deaths, one cardiovascular and 12 non-cardiac deaths (Table 1). Only one aviator, who had a myocardial infarction, died while on active duty. Forty-two (10%) aviators had significant medical endpoints associated with SVT. There were no sudden deaths due to SVT. There were 5 episodes of syncope and 37 episodes of presyncope. The presyncopal episodes included 20 aviators with signs of cerebral hypoperfusion with lightheadedness and 6 with tunneling of vision. Eleven aviators during their episodes of SVT manifested signs of cardiac hypoperfusion with anginal chest discomfort or dyspnea. An additional 22 (5%) aviators had hemodynamically stable recurrent episodes of sustained SVT.

CARDIAC = 12	CARDIOVASCULAR = 11	NON-CARDIAC = 12
7 MI	1 RUPTURED AAA	7 CANCER
2 CCM		2 SUICIDE
1 CAD-CHF		1 SEPSIS
1 PROSTHETIC VALVE CLOT		1 HIV PNEMONIA
1 UNKNOWN DIED DURING SLEEP		1 PNEUMONIA

Table 1. There were 25 deaths in the 430 aviators with SVT. SVT was not a cause or factor in any of the 25 deaths. MI = myocardial infarction, CCM = congestive cardiomyopathy, CAD = coronary artery disease, CHF = coronary heart failure, AAA = abdominal aortic aneurysm

3.4 Hemodynamically Unstable SVT

Hemodynamically unstable SVT occurred in 42 (10%) of the 430 aviators with SVT. Thirty-eight (90%) of these aviators had unstable SVT as the initial manifestation of SVT. None of the 38 aviators had cofactors which were useful in identifying them prior to the initial SVT event. Forty-one aviators had unstable SVT events which occurred spontaneously. These aviators promptly self-referred to local medical treatment facilities. One episode of hemodynamically unstable SVT was centrifuge-induced during TAC +Gz training. Four (10%) of the 42 aviators later progressed to unstable SVT following the initial diagnosis of SVT. These four aviators had previously documented sustained SVT. Three of the four initially presented with recurrent sustained SVT and the fourth had initially presented with a single episode of sustained SVT.

3.4.1 *Relationship between sustained SVT and hemodynamically unstable SVT*

Thirty-three (87%) of the 38 aviators presenting with unstable SVT had sustained SVT; only 51 (13%) of the 392 aviators without unstable SVT on the index ACS evaluation had sustained SVT. Aviators presenting with sustained SVT were at higher risk for the additional diagnosis of unstable SVT (relative risk of 27.2, $p < 0.001$). Nineteen (50%) of the 38 aviators who initially presented with unstable SVT had recurrent sustained SVT. An additional 23 aviators had stable recurrent sustained SVT. Aviators presenting with recurrent sustained SVT had an increased relative risk of 9.2 ($p < 0.001$) for associated unstable SVT.

3.4.2 *Risk for subsequent hemodynamically unstable SVT events*

Five (13%) of the 38 aviators initially presenting with unstable SVT had a subsequent episode of unstable SVT. Four (1%) of the 392 aviators initially presenting with stable SVT had a subsequent unstable SVT event. Aviators with a prior history of unstable SVT have a demonstrated capacity to recur and have an increased relative risk (RR) of 7.1 ($p < 0.001$) for a subsequent unstable SVT event.

3.5. Hemodynamically Stable Recurrent Sustained SVT

During the time period of this study, 22 (5%) aviators had stable recurrent sustained SVT. The stable SVT event occurred at the aviators' home bases in 18 (82%) of these 22 cases. In the remaining four cases, the stable recurrent sustained event occurred during the index ACS evaluation. Twenty-one (95%) of 22 aviators self-referred within 24 hours to local flight surgeons, emergency rooms or ACS physicians due to the sudden onset of persistent palpitations. One of the 22 aviators had stable recurrent sustained SVT induced during local treadmill testing.

3.5.1 *Risk for subsequent episodes of hemodynamically unstable SVT*

Three (13%) of the 23 aviators, initially presenting with stable recurrent sustained SVT, subsequently developed unstable SVT. Only one of the 369 stable aviators, initially presenting without recurrent sustained SVT, subsequently developed unstable SVT. Aviators with a prior history of stable recurrent sustained SVT were at increased risk (RR 48.1, $p < 0.001$) for the subsequent development of unstable SVT.

3.5.2 *Risk for subsequent episodes of hemodynamically stable sustained SVT*

Five (22%) of the 23 aviators initially presenting with stable recurrent sustained SVT and 6 (2%) of the 369 stable aviators initially presenting without recurrent sustained SVT had subsequent sustained SVT events. Aviators initially presenting with stable recurrent sustained SVT were at increased risk (RR 13.4, $p < 0.001$) for developing subsequent sustained SVT events.

3.5.3 *Initial presentation with hemodynamically stable nonsustained SVT*

Table 2 illustrates the predictors of outcome for subsequent sustained events for each of the initial hemodynamically stable SVT presentations. Of the 322 aviators initially presenting with nonsustained SVT, three (0.9%) had a subsequent sustained SVT and none subsequently developed unstable SVT. One (0.5%) of the 214 aviators, initially presenting with a single nonsustained episode of SVT, had a subsequent sustained SVT event. Of the 108 aviators initially presenting with recurrent non-sustained SVT, two (2%) had subsequent sustained SVT events. Aviators initially presenting with stable nonsustained SVT were at minimal risk for the subsequent development of subsequent episodes of sustained SVT.

	SUBSEQUENT	
INITIAL EVENT	SUSTAINED EVENTS	HEMODYNAMICALLY UNSTABLE
Single Nonsustained SVT	1/214 (0.5%)	
Recurrent Nonsustained SVT	2/108 (2%)	
Single Sustained SVT	3/ 28 (11%)	1/28 (4%)
Recurrent Sustained SVT	5/ 23 (22%)	3/23 (13%)

Table 2. Predictors of outcome for subsequent sustained events for each of the initial stable SVT presentations

3.5.4 *Initial presentation with hemodynamically stable sustained SVT*

Table 2 illustrates the predictors of outcome for subsequent sustained events for each of the 51 aviators initially presenting with stable sustained SVT. Eight (16%) had subsequent sustained SVT events and four of these eight were unstable SVT. Of the 28 aviators initially presenting with stable single sustained episodes of SVT, three (11%) had subsequent sustained SVT events and one was unstable SVT. Of the 23 aviators presenting with stable recurrent sustained SVT, five (22%) had subsequent sustained SVT events and three were unstable SVT. Aviators presenting with stable sustained SVT had an increased relative risk of 16.8 ($p < 0.001$) for a subsequent sustained SVT and half of these events were unstable SVT.

• No Subsequent Recurrence	25 / 51 (49.0%)
• Recurrence in 0 to 1 years	17 / 51 (33.3%)
• Recurrence in 1 to 2 years	3 / 51 (6.0%)
• Recurrence in 2 to 3 years	2 / 51 (3.9%)
• Recurrence in 3 years or more	4 / 51 (7.8%)

Table 3. The recurrences by year for the 51 aviators who initially presented with sustained SVT and had a subsequent sustained SVT event

Table 3 illustrates the rate of recurrence for the second sustained SVT event for the 51 aviators initialy presenting with stable sustained SVT. Twenty-five (49%) aviators of the 51 aviators had no subsequent sustained SVT events. Of those aviators having a subsequent sustained event, 17 (33.3%) had events within one year three (6.0%) had events with 1-2 years, two (3.9%) had events within two to three years and four (7.8%) had events which occurred after three years.

3.6 SVT Associated with AF or MAT

Nineteen aviators whose initial rhythm event was stable SVT also had other supraventricular tachycardias: four had atrial fibrillation (AF) and 15 had multiform atrial tachycardia (MAT). An additional 23 aviators with only SVT on the index ACS evaluation later manifested MAT, AF or AFL on subsequent ACS evaluations or reported them on their questionnaires. One aviator initially presenting with unstable single sustained SVT and another initially presenting with unstable recurrent sustained SVT subsequently developed stable AF.

3.6.1 *Risk for hemodynamically unstable SVT*
None of the 19 aviators initially presenting with SVT and either AF or MAT rhythms had unstable SVT and none subsequently developed unstable SVT.

3.6.2 *Risk for subsequent repetitive events*
One of the four aviators initially presenting with SVT and AF, and two of the 15 aviators initially presenting with SVT and MAT, subsequently developed AF. Eight of the 373 aviators initially presenting with stable SVT without MAT or AF subsequently had recurrent runs of MAT, AF or AFL. Aviators initially presenting with SVT and other forms of SVT were at increased risk (RR 7.4, p 0.001) for subsequently manifesting either MAT, AF, or AFL.

3.7 Pre-excitation Syndromes

There were 18 aviators with pre-excitation syndromes and all were identified on the index ACS evaluation for SVT. Seventeen had Wolff-Parkinson-White (WPW) syndrome and one had Long-Ganong-Levine (LGL) syndrome.

3.7.1 *Association with hemodynamically unstable SVT*
Six (33%) of the 18 aviators with pre-excitation had unstable SVT events on initial presentation. Only 36 (9%) of the 412 aviators without pre-excitation, had unstable SVT events. Aviators with pre-excitation syndrome were at increased risk (RR 3.8, p 0.001) for unstable SVT when compared to aviators without pre-excitation.

3.7.2 *Association with recurrent sustained SVT*
Twelve (67%) of the 18 aviators with pre-excitation syndrome had stable SVT. Three (33%) of the 12 had recurrent sustained SVT. Of the 376 stable aviators without pre-excitation syndrome, 18 (5%) had recurrent sustained SVT. Aviators with stable pre-excitation syndrome were at increased risk (RR 5.2, p 0.002) for recurrent sustained SVT.

3.8 Congestive Cardiomyopathy

Four aviators had a dilated cardiomyopathy presumed secondary to a viral myocarditis. One of these four had unstable SVT. While this early trend suggests an increased relative risk for unstable SVT, the numbers are too small to extract meaningful information.

3.9 Other Cofactor Data

No other diagnoses were predictive of unstable SVT or stable recurrent sustained SVT. Diagnoses evaluated were valvular heart disease including mitral valve prolapse or aortic insufficiency, coronary artery disease, ventricular tachycardia, bundle branch blocks, thyroid disease or underlying dysrhythmic substrate (such as frequent premature atrial or ventricular contractions or pairing). The SVT duration or maximal heart rate, social habits such as ethanol, caffeine, or nicotine use were not useful in predicting subsequent unstable SVT or stable recurrent sustained SVT events.

3.10 Invasive Data

A total of 58 electrophysiologic studies (EPS) and 154 cardiac catheterizations were performed. The EPS did not predict subsequent hemodynamically unstable SVT or recurrent sustained SVT. Importantly, the EPS did not detect previously unrecognized pre-excitation or conduction disorders. Forty-six (11%) of the 430 aviators had gradable coronary artery disease by cardiac catheterization. None of the 26 aviators with clinically normal treadmill, thallium and coronary artery fluoroscopy test results had gradable coronary artery disease.

3.11 In Flight Events

Only five SVT events were reported during flight. Three of these events were self terminating hemodynamically stable SVT events associated with palpitations which did not impact the mission. In two aviators, hemodynamically unstable SVT evens resulted in aborted missions. In the first case, the pilot noted the sudden onset of palpitations shortly after takeoff, associated with lightheadedness, dyspnea and precordial chest tightness. In the second case the pilot noted the sudden onset of palpitations associated with lightheadedness. In both cases, the SVT was self terminating and each pilot landed safely.

4. DISCUSSION

This review validates the initial premise that certain subsets of aviators with SVT may be returned with minimal aeromedical risk to flying duties. The data illustrate that the initial SVT presentation characteristics are useful in predicting subsequent SVT events. Aviators presenting with stable nonsustained SVT were at low risk for subsequent sustained SVT or unstable SVT events. As the frequency and duration of the initial episode of SVT increased, so did the occurrence of subsequent recurrent sustained and unstable SVT events. Those aviators presenting with sustained SVT had an increased risk for subsequent sustained SVT and unstable SVT. Aviators with stable recurrent sustained SVT were at the highest risk for subsequent episodes of sustained SVT.

Selected subsets of SVT clearly are at an increased occupational risk. Aviators presenting with unstable SVT have an increased relative risk of 7.1 for a subsequent unstable SVT event compared to aviators presenting without unstable SVT. Aviators presenting with stable recurrent sustained SVT were 48.1 times more likely to have a subsequent unstable SVT event than those aviators who did not present with stable recurrent sustained SVT. Aviators presenting with a subsequent sustained SVT event in less than 3 years are considered to be frequently recurrent and to represent too high a risk for continued flight duties.

The diagnosis of pre-excitation pattern on ECG in association with SVT was also predictive of unstable SVT and subsequent recurrent sustained SVT events. Aviators with pre-excitation syndrome had a 3.8-fold increased relative risk for unstable SVT and a 5.2-increased relative risk for stable recurrent sustained SVT. Unstable SVT occurred in only those aviators with sustained SVT and pre-excitation. None of the aviators with pre-excitation and nonsustained SVT developed subsequent unstable SVT or subsequent sustained SVT events. These data support the present policy to disqualify aviators with pre-excitation patterns and sustained SVT and suggest further review of aviators with nonsustained SVT and pre-excitation.

No other cofactor was useful in predicting subsequent hemodynamically unstable SVT or stable recurrent sustained events. Aviators with valvular heart disease including mitral valve prolapse and aortic insufficiency, coronary artery disease, left or right bundle branch blocks, ventricular tachycardia, inactive pulmonary sarcoidosis or dysrhythmic substrate were not at increased risk for unstable SVT or stable recurrent sustained SVT.

Aviators presenting with SVT and AF or MAT were not at increased risk for unstable SVT. While the combination did not predict subsequent hemodynamically unstable SVT or recurrent sustained SVT events, it did predict subsequent hemodynamically stable supraventricular tachydysrhythmias such as atrial fibrillation, atrial flutter or multiform atrial tachycardia with an increased relative risk of 7.4.

Prior to this review, aviators with single runs of stable SVT were considered for waiver if underlying gradable coronary artery disease, pre-excitation syndrome, valvular heart disease including mitral valve prolapse, ventricular tachycardia or left bundle branch block could be excluded. Based on this review, current USAF guidelines recommend an evaluation at the aviator's home base for a single episode three to ten beat run of SVT. The local evaluation will include an internal medicine evaluation to exclude precipitating cofactors and underlying pathologic conditions, laboratory studies including thyroid function tests, a treadmill, an echocardiogram and Holter monitors performed monthly for three months.

Aviators with unstable SVT, sustained SVT or recurrent runs of SVT should be referred for a complete ACS evaluation. The ACS evaluation will include a history and physical, laboratory studies including thyroid function tests, treadmill test, Holter monitor and echocardiography. Aviators older than 35 years will also receive a thallium scan and cardiac fluoroscopy. Invasive studies will no longer be required unless clinically indicated. A single episode of nonsustained SVT will not require ACS re-evaluation. ACS re-evaluation every three years will be required for recurrent or sustained SVT.

Unrestricted flying duties will be considered for aviators with a single episode of stable nonsustained SVT or a single stable episode of sustained SVT with no other disqualifying abnormality. Nonsustained or sustained SVT associated with mitral valve prolapse, sarcoidosis, bundle branch blocks or other valvular heart diseases (except aortic insufficiency) may resume unrestricted flying duties.

Nonhigh performance flying duties will be considered for aviators with stable recurrent sustained SVT with no other disqualifying abnormality when the interval between sustained events is three or more years. Nonsustained SVT associated with minimal coronary artery disease, ventricular tachycardia or aortic insufficiency, and a single sustained episode of SVT associated with ventricular tachycardia or aortic insufficiency may also be returned to nonhigh performance flying duties.

Permanent disqualification will be considered for aviators with hemodynamically unstable SVT, hemodynamically stable recurrent sustained SVT when the interval between sustained events is less than three years, any SVT with pre-excitation and sustained SVT with gradable coronary artery disease.

In summary, carefully selected aviators with SVT may be returned safely to flying duties. Those aviators with certain underlying pathologic diagnoses, hemodynamic instability, frequent recurrent sustained SVT and pre-excitation syndrome represent a higher occupational risk and disqualification should be considered.

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SARCOIDOSIS IN U.S. MILITARY AVIATORS

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INTRODUCTION

Sarcoidosis is a systemic granulomatous disease of unknown etiology and is generally a benign, self-limiting disorder. Myocardial involvement has been known since 1929 (1), but several articles published in the early 1970's indicated that myocardial involvement was a more common and serious problem. In 1974, Fleming reported on 50 cases of myocardial sarcoidosis with cardiac involvement confirmed in 20 cases by necropsy. He suggested that myocardial sarcoid was probably underdiagnosed and was not a rare condition (2). In 1984, he also suggested that sarcoidosis was frequently overlooked until sudden death occurs, often in relatively young people, 25-54 years of age (3). In 1976, Matsui, et al., reported in a Japanese population on 72 individuals with sarcoidosis at autopsy. Fifty-eight percent of these individuals died because of myocardial involvement. Most of these deaths were sudden and the diagnosis was generally not suspected during life. In addition, myocardial involvement was apparently a late complication and was not predicted by progressive pulmonary involvement (4). In 1977, Roberts et al., reported on 113 patients found to have myocardial sarcoidosis at autopsy. Seventy-nine percent had cardiac dysfunction due to myocardial involvement, 67% experienced sudden death, and 23% developed congestive heart failure. Most patients with myocardial sarcoid presented initially with cardiac symptoms and most had little or no evidence of other organ involvement. In 16%, sudden death was the initial manifestation of sarcoidosis (5). In view of the possible catastrophic consequences of sudden unexpected death or sudden incapacitation of a military aviator, the United States Air Force (USAF) became concerned about the implication of myocardial sarcoidosis.

Prior to 1978, all USAF flyers with sarcoidosis were evaluated at the local flight surgeon's office. After they became stable and the findings of sarcoid resolved, they were returned to flying duties with a local waiver. The details of this local evaluation were not prescribed by protocol and were based solely on the judgement of the local physician. In 1978, the USAF initiated the sarcoidosis study group. This program was initiated to solve 2 basic problems. First, clinical studies indicated that a more thorough evaluation was required to examine the possibility that an individual with a history of pulmonary sarcoidosis may have asymptomatic but significant myocardial granulomas. This program also provided a mechanism for recurrent periodic evaluations to ensure the aviator's continued fitness for flying. The second objective of the sarcoid study group was to perform these evaluations in a systematic fashion with periodic review to determine the outcome of individuals with a history of sarcoidosis to insure that the prognosis of this group was consistent with continued flying duties.

METHODS

Beginning in July 1978, all aviators with newly diagnosed or suspected sarcoidosis were referred to the Aeromedical Consultation Service (ACS) at Brooks AFB for evaluation and follow-up. The evaluation included a history, physical, ophthalmology evaluation, chest X ray, skin testing (PPD, mumps, and monilia antigens), Kveim test, exercise treadmill test with thallium myocardial scan, Holter monitor, echocardiography, pulmonary function testing, gallium thoracic and abdominal scans, screening lab studies, coccidioidomycosis and histoplasmosis titer, 24-hour urine for calcium, and serum angiotensin converting enzyme. Those individuals without tissue diagnosis underwent flexible bronchoscopy and transbronchial biopsy. In 1980, the requirement for bronchoscopy was amended to include only those patients who required that procedure for clinical reasons. Kveim testing was removed as it was not possible to obtain a reliable source for antigen. Gallium scanning was also stopped unless strong clinical indications existed.

Initially, all aircrew members with a diagnosis of sarcoidosis were grounded for an observation period of 2 years. If the disease became inactive for 2 years, waiver for flying duties was then granted. Those with evidence of persistent active disease were disqualified. Individuals were also disqualified for evidence of neurosarcoid, posterior uveitis, or significant ECG findings such as ventricular or supraventricular tachycardia, bundle branch block or an infarction pattern. Aviators were required to have periodic reevaluations every 3 years or sooner if test results warranted. In 1985, the initial grounding period was reduced from 2 years to 1 year and follow-up intervals were increased to a maximum level of 5 years. The medical records on all aviators seen at the ACS with sarcoidosis from July 1978 through March 1991 were reviewed. These individuals were then contacted by telephone and interviewed by a physician to identify medical problems or symptoms since their last ACS evaluation.

RESULTS

Eighty-one aviators were seen at the ACS with a diagnosis of sarcoidosis. All were men and their mean age was 34 years +/- 7 years. The group included 72 (78%) caucasian, 8 (10%) black, and 1 (2%) American Indian. Prior to the diagnosis of sarcoidosis, all were physically qualified to fly U.S. Air Force aircraft. Sixty-five (80%) were seen more than once for a mean follow-up of 6 years. Telephone contact was made with 79 (95%) for a mean telephone follow-up of 9 years.

The diagnosis of sarcoidosis was confirmed by biopsy in 68 and by Kveim reaction in one individual. In 12 of the individuals, a biopsy was not done or did not show non-caseating granuloma. In these 12, the diagnosis was made by the combination of chest X ray, presentation and clinical course.

The initial presentation for 52 (64%) individuals was an abnormal chest X ray that was obtained on a routine basis as part of the annual flight physical examination. The majority of these individuals were identified in the early years of the study since chest X rays were obtained annually as part of the routine flying physical prior to 1979. By the time aviators were seen at the ACS, at least 1 year had elapsed since their initial diagnosis of sarcoidosis, and 45% of the chest X rays remained abnormal. Hilar adenopathy was the most common finding in 24 (46%), 6 (11%) had infiltrates, and 3 (6%) had hilar adenopathy with infiltrates. Some unusual findings were a nodule which eventually resolved and another had bullous lung disease.

Twenty-nine (36%) aviators presented with a complaint which initiated testing leading to the diagnosis of sarcoidosis. The leading complaints were: cough 8 (27%), arthralgia 7 (24%), fatigue/weakness 6 (20%), swollen ankles 5 (17%), exertional dyspnea or shortness of breath 5 (17%), erythema nodosum 4 (13%), fever 3 (10%), rash 2 (6%), and/or neurologic complaint 2 (6%).

Two aviators had non-reperfusing defects on thallium scan, but declined further invasive diagnostic testing. One of these

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individuals remains asymptomatic after 10 years, the other died 8 years later of penicillin anaphylaxis, representing the only death in the study population. Nine (11%) had tachydysrhythmias which may have been associated with myocardial sarcoidosis, but other possible causes could not be eliminated. There was 1 with brief runs of ventricular tachycardia (VT), and there were 6 with nonsustained supraventricular tachycardia (SVT) found on Holter. There were 2 individuals, 1 with brief runs of VT and another with frequent runs of nonsustained SVT who were also found to have mitral valve prolapse (MVP). Incidental MVP was found by auscultation and confirmed by echocardiography in 5 (6%) of the individuals in this study. Those with both MVP and sarcoidosis were much more likely to have significant ectopy or tachydysrhythmias as compared to the group with sarcoid only (Table I). During the course of follow-up, there were no episodes of sudden death, syncope, presyncope, or congestive heart failure. In addition, there were no cases of myocardial sarcoidosis proven by biopsy or autopsy. However, there were no clinical indications for biopsy in any of these individuals, and the autopsy that was performed did not show evidence of myocardial sarcoidosis.

TABLE I. ARRHYTHMIA FINDINGS

Significant arrhythmias consist of frequent PVC's (>1% of all beats on Holter monitor), pairing, and tachydysrhythmias.

	SIGNIFICANT ECTOPY	SVT	VT
WHOLE GROUP	17% (14/81)	9% (7/81)	2.4% (2/81)
SARCOID ONLY (NO MVP)	16% (12/76)	8% (6/76)	1.3% (1/76)
SARCOID + MVP	40% (2/5)	20% (1/5)	20% (1/5)

Pulmonary function testing was abnormal in 15 (18%) of the initial evaluations, all abnormal tests showed mild to moderate obstructive patterns. At the time of their last evaluation, 10 of these remained abnormal, the other five became normal. Four (5%) of the 81 individuals progressed from mild obstruction (60-69% FeV1/FVC) to moderate obstruction (50-59% FeV1/FVC). One individual had progressive deterioration in both PFT's and chest X ray consistent with a progressive fibrosis. There were 5 individuals with new mild obstructive patterns on their PFT's at the time of their last evaluation.

Six (7.3%) had active sarcoidosis or sarcoid sequelae at the time of their last evaluation. One of these individuals developed unilateral hearing loss 2 weeks after presenting with an abnormal chest X ray. Tomography of the head showed a 1cm density in the brain. Treatment with steroids resulted in a return of auditory function and resolution of the lesion. Another continues to have progressive pulmonary fibrosis and reactive airway disease after 8 years of follow-up. Four individuals had indications of disease activity on their most recent evaluation such as increased infiltrates on chest X ray and/or elevated liver enzymes.

DISCUSSION

By the 1970's, the general impression of many researchers in sarcoidosis was that myocardial involvement was an underdiagnosed condition of clinical concern. Their impression was derived from either autopsy studies or case series studies of individuals referred to a tertiary medical facility for symptomatic disease. However, there were no studies that established the long-term prognosis of an individual presenting with sarcoidosis but asymptomatic from a cardiac standpoint.

In these 81 aviators followed for 9 years, there were no episodes of sudden death or syncope, and no aviator was found to develop myocardial sarcoidosis by the testing applied. The findings of nonsustained VT and SVT in nine subjects both with and without MVP may have resulted from small granulomas, but are probably unrelated. Ventricular tachycardia has been reported as one of the more ominous hallmarks of sarcoid heart disease (6,7,8,9). Supraventricular tachyarrhythmias are commonly reported (6,9,10). Regrettably, rhythm and conduction disturbances are also relatively common in otherwise healthy people without sarcoidosis, so the specificity of these findings is low. However, these individuals remained asymptomatic over the course of the study, and no other testing was felt to be clinically indicated. The additional finding of MVP in 6% of aviators was also felt to be an incidental and unrelated finding.

Of note, in 1976, a 29-year-old USAF aviator died suddenly at home with myocardial involvement of previously undiagnosed sarcoidosis. This aviator presents a disturbing but predictable problem since most individuals with sarcoidosis are probably not diagnosed and sudden death is a well described presenting symptom of myocardial sarcoidosis. This case, however, does not alter our finding that individuals with sarcoidosis, but asymptomatic from a cardiac standpoint, have a good long-term prognosis.

The ability to visualize myocardial tissue has changed dramatically over the course of this study. Tests available during most of this effort were neither specific nor sensitive for identifying myocardial granulomas. Future efforts in individuals suspected of having myocardial sarcoid will probably benefit from new modalities such as MRI (6,11).

Although the overall prognosis is very favorable, we feel the high number of tachydysrhythmias and the small but definite possibility of myocardial disease still warrant some continued surveillance. Aviators with sarcoidosis should remain disqualified until the disease is inactive. This means that the aviator is asymptomatic, the chest radiograph resolves (hilar adenopathy may remain but should be stable in size), and there is no other organ involvement. Prior to recommendation for flying waiver, the aviator should undergo an evaluation to include history, physical, chest radiograph, pulmonary function testing, 24-hour Holter monitor, and laboratory testing (angiotensin converting enzyme, liver enzymes, and blood count). Exercise stress testing, thallium scintigraphy, gallium scan, echocardiography, etc., need not be done unless clinically indicated. Magnetic resonance imaging holds some promise in screening for CNS or myocardial sarcoid, however, further testing needs to be done before this modality can be employed routinely for occupational evaluations. If the above studies show that the disease is quiescent, we feel that the aviator may return to flying duties. We also recommend periodic reevaluation, every two years, since myocardial involvement may appear many years after the initial pulmonary manifestation of disease. If there is myocardial or neurologic sarcoid, or clinical evidence of other organ involvement, then the aviator should be grounded permanently. Air Commodore Hull of Great Britain has reported favorable use of a similiar policy regarding sarcoidosis in RAF aircrew over the past 14 years (12).

CONCLUSION

In our group of 81 aviators, 1 aviator was permanently disqualified for neurosarcoid, 2 for pulmonary complications, and 11 for findings suggestive of myocardial involvement (tachydysrhythmias or abnormal thallium scan). There was one death unrelated to sarcoidosis. The natural history of sarcoidosis in our aviators is much more favorable than suggested by the clinical literature.

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THE AEROMEDICAL RISK ASSOCIATED WITH ASYMPTOMATIC CHOLELITHIASIS IN USAF PILOTS AND NAVIGATORS

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SUMMARY

The USAF aeromedical policy regarding incidentally discovered, asymptomatic cholelithiasis requires the aircrew to undergo cholecystectomy prior to being considered for return to flying duties. The merit of continuing this USAF policy was evaluated at the request of the USAF Surgeon General. A review of the medical literature predicted a 1% to 4% annual event rate of acute cholecystitis in individuals with previous asymptomatic cholelithiasis. The prevalence of asymptomatic cholelithiasis in USAF pilots and navigators was determined to be 2% to 3%, based on data acquired at the Ellingson Aerospace Medicine Consultation Service (ACS). Of 11,685 pilots and navigators evaluated at the ACS, 0.7% (n = 80) were diagnosed with cholelithiasis or previous cholecystectomy. Between 1972 to 1992, 16,232 man-years of pilot and navigator exposure to asymptomatic cholelithiasis was estimated to have occurred; however, only 50 cases with a diagnosis of cholecystectomy or cholelithiasis were reported in the USAF Surgeon General waiver file. Mortality and morbidity associated with cholecystectomy by either open or laparoscopic technique were reported as 0.2% and 5%, respectively. Using 1994 USAF pilot and navigator manpower data and the worse case scenario of a 0.7% occurrence for the onset of acute symptoms associated with previously asymptomatic cholelithiasis, up to five aircrew would be expected to experience acute symptomatology at some time during 1994. However, if every pilot and navigator flew 200 to 1,000 flying hours during 1994, 0.1 to 0.6 individuals, or essentially none, would be predicted to experience acute symptoms related to gallstones inflight. The natural history of cholelithiasis in USAF pilots and navigators is more favorable than suggested by the clinical literature. The inflight risk of experiencing acute symptoms associated with previously asymptomatic cholelithiasis is essentially nonexistent in USAF aircrew.

INTRODUCTION

Infrequently, USAF aircrew have presented with asymptomatic cholelithiasis during incidental diagnostic testing. Historically, these aviators have been grounded until an occupational cholecystectomy has been performed. Grounding was based on a perceived excessive risk for developing acute symptomatology while inflight. Potential complications included severe biliary colic, acute cholecystitis, acute pancreatitis, common duct obstruction, ascending cholangitis, gallbladder cancer, and gallstone ileus. Cholelithiasis could also present with less severe or acute symptoms that might not have been suddenly incapacitating, but could effect mission completion and readiness. The merit of continuing the USAF policy for grounding aircrew with asymptomatic cholelithiasis until a cholecystectomy had been

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performed was evaluated at the request of the USAF Surgeon General. The objectives of this study were: 1) to determine the long term outcome of USAF pilots and navigators who had asymptomatic cholelithiasis; 2) to determine the prevalence of asymptomatic cholelithiasis in USAF pilots and navigators; and 3) to evaluate the risk associated with occupational cholecystectomy for asymptomatic cholelithiasis versus the aeromedical risk for flying safety and mission completion. The study was retrospective, and the setting involved all evaluees who had had evaluations at the Ellingson Aerospace Medicine Consultation Service (ACS) at Brooks AFB, Texas, during the period 1955 to 1992. The ACS is a centralized USAF referral center which performs aeromedical evaluations for aviators to determine their fitness for flying duties.

METHODS

The methodology used included: 1) a medical literature review regarding the natural history of cholelithiasis in the general population; 2) a review of the ACS data file from 1955 through 1992 for all USAF pilots and navigators who were evaluated and assigned a diagnosis of cholelithiasis or cholecystectomy; 3) a review of the USAF Surgeon General aircrew waiver file from 1972 through 1992 for all USAF pilots and navigators who were assigned a diagnosis of cholelithiasis, cholecystectomy, or a related condition; 4) USAF pilot and navigator annual manpower data were obtained from the USAF Military Personnel Center for the period 1972 through 1992 and used as the denominator in calculations involving the USAF Surgeon General aircrew waiver file; 5) all USAF aircrew evaluated at the ACS underwent screening KUB abdomen radiographs, which were reviewed for presence of radiopaque gallstones over a 7-year period from 1986 through 1992; and 6) surgical morbidity and mortality associated with the therapeutic options for cholelithiasis were reviewed with the Division of Surgery at Wilford Hall Medical Center (WHMC), Lackland AFB, Texas, for the management of cholelithiasis.

RESULTS

A medical literature review of the natural history of cholelithiasis predicted a 1% to 4% annual event rate of acute symptomatology associated with asymptomatic gallstones in the adult general population (1-9). Correlating the findings of these studies to the USAF pilot and navigator population was difficult because of the age, increased female:male ratio, and heterogeneity of the study populations. These studies also generally did not clearly separate the patients with severe, acute incapacitating symptoms from those with more slowly progressive symptoms. Finally some of these studies reported on both patients who were symptomatic and asymptomatic at baseline without separating the two groups in their findings (1,3). Ransohoff, et al. (6,7) reviewed the above studies and several others to arrive at the recommendation of expectant management of asymptomatic gallstones based on projected risk of death and loss of life expectancy. They concluded, "expectant management... applies to men and women of all ages... until a perfectly safe, effective, convenient and inexpensive treatment is developed." Possible exceptions to this universal rule apply only to the following groups: children, New World Indians, patients with calcified gallbladders on radiographic studies, patients with Sickle Cell Disease, and patients with large (greater than 3 cm) gallstones (7,8). Children were reported to universally become symptomatic (8). New World Indians and patients with large stones or calcified gallbladders are reported to have an increased incidence of gallbladder cancer (7) Patients with Sickle Cell Disease have attacks of abdominal pain which can mimic acute cholecystitis and emergency cholecystectomy is reportedly much more dangerous than an elective procedure in this group (8). Interestingly, patients with diabetes mellitus, traditionally indicated for removal of asymptomatic stones, were now felt candidates for expectant management. This change was due to their higher morbidity and mortality,

because of concomitant medical problems, during even elective cholecystectomy (8).

From an aeromedical perspective aircrew members (unless of New World Indian heritage) probably fall within the universal guidelines of expectant management of asymptomatic cholelithiasis because the other medical conditions listed above should be disqualifying for flying duties.

Gallstones are classified into two principal types: cholesterol and pigment. Cholesterol gallstones account for 75% of gallstones found in the United States of America (USA) population and populations of European descent. Greater than 90% of cholesterol gallstones are radiolucent. Pigment gallstones account for about 25% of gallstones and are composed of two types. The black pigment gallstones usually are associated with old age or individuals who have had rapid weight loss associated with illness. The brown pigment gallstones are more common in the orient, however, the incidence decreases with the Westernization of culture and diet. They are also found in individuals who have had an infection of the biliary system. Overall, approximately 15% and 20% of all gallstones are radiopaque.

The prevalence of cholesterol gallstones in the USA general population has been reported as high as 17%. There is up to a 3.1 female to male ratio after puberty related to estrogen which diminishes after menopause. The incidence within some populations as mentioned, such as American Indians, is far greater than whites, whose incidence is greater than blacks, with an estimated 75% of American Indian women over the age of 25 being affected. On autopsy in the United States, 20% of the 75-year-old men and 35% of 75-year-old women were found to have gallstones on autopsy. Gallstones tend to grow for the first two to three years, at which point growth tends to stabilize; 85% of all gallstones are less than 2 cm in diameter (9). Existing data indicate that 10% of patients will develop symptoms in the first five years after diagnosis of asymptomatic cholelithiasis and approximately 20% by 20 years. Almost all patients will experience symptoms for a period of time before they develop a complication (9). It is estimated that 30% to 50% of population who have gallstones are truly asymptomatic. The other 40% to 65% of the population with gallstones, however, manifest recurrent symptoms of chronic cholelithiasis as frequently as daily or as seldom as once every few years. These previously asymptomatic people were not identified as having an initial period of increased risk or an identifiable "honeymoon period."

Of the 3,451 KUB radiographs taken of the abdomen at the ACS, from 1986 through 1992, 16 cases of radiopaque gallstones were found. The calculated occurrence rate was 0.46% (16/3,451 = 0.0046). Based on the literature value that approximately 15% to 20% of gallstones are radiopaque, an estimated 2% to 3% (0.0046/0.15 = 0.031 and 0.0046/0.2 = 0.023) prevalence of gallstones within the USAF pilot and navigator population was derived.

The ACS data file for the 37-year period from 1955 through August 1992 had 11,685 pilots and navigators registered. The age range was from 24 to 61 years, the mode was 43 years, and the mean was 42 years. There were 35 female evaluees represented; their age ranged from 24 to 36 years; the first female evaluation occurred in 1980. Eighty male evaluees had been diagnosed with either cholelithiasis or cholecystectomy for a calculated occurrence of 0.7% (80/11,685 = 0.007).

The USAF Surgeon General aircrew waiver file for the 21-year period 1972 through August 1992 had 50 cases registered who had been assigned the diagnosis of cholelithiasis, cholecystectomy, or a related condition. USAF pilot and navigator manpower data from the USAF Military Personnel Center showed that during that period the number of USAF pilots and navigators on active

duty ranged from 53,727 in 1972 to 26,678 in 1992, the mean number was 38,647 aircrew per year. A total of 811,589 man-years of exposure to all conditions occurred during the period documented by the waiver file.

Using the previously calculated 2% to 3% prevalence determined for asymptomatic gallstones within the USAF pilot and navigator population, a predicted 16,232 to 24,348 (811,589 x 0.02 = 16,232 and 811,589 x 0.03 = 24,348) man-years of exposure to gallstones would have occurred during the period 1972 through 1992. However, within the waiver file only 50 cases had been reported and 15 of these cases were incidentally detected and reported as asymptomatic. From the general population estimates that 1% to 4% of people with asymptomatic gallstones will have acute symptoms each year, 162 to 974 (16,232 x 0.01 = 162 and 24,348 x 0.04 = 974) episodes of acute symptoms would have been predicted to have occurred within this group of aircrew. This suggests that symptomatic cholelithiasis has occurred far less frequently in our pilots and navigators then the general medical literature value would have predicted. The annual occurrence of acute symptoms for USAF pilots and navigators was calculated to be 0.1% to 0.2% [e.g., 35 aircrew found to be symptomatic or who had undergone cholecystectomy for presumed symptoms occurring out of 16,232 (2%) to 24,348 (3%) man-years of exposure to asymptomatic gallstones = 0.002 to 0.001 occurrence, respectively].

Clinical management options from the Division of Surgery at WHMC were: 1) Cholecystotomy, which only removes the gallstone(s) from the gallbladder. Since the majority of these patients would have a recurrence within five years, this was not considered an appropriate procedure for aircrew. 2) Open cholecystectomy, which had in the past been the gold standard for the treatment of gallstones. It is curative of the problem since it removes the gallbladder, as well as the stone. The procedure is associated with a 3- to 5-day hospital stay and four weeks of post-operative pain/disability. The mortality is 0.2% and morbidity is less than 5% for the procedure. 3) A new procedure, first performed in 1988, is the laparoscopic cholecystectomy which again is curative of the problem, removing gallstones and gallbladder. Typically only a 1- to 2-day hospital stay is required, far less post-operative pain is felt and a return to duty occurs in 1- to 2-weeks as compared to the open technique. With both procedures, a return to flying status occurs in typically eight weeks. 4) Other therapeutic options such as dilutional therapy and lithotripsy are not recommended for aircrew because of their highly variable response accompanied with frequent recurrence of gallstones (9).

DISCUSSION

Using pilot and navigator manpower data estimates for fiscal year 1994, 22,275 pilots and navigators will be on active duty. With a 2% to 3% prevalence of asymptomatic gallstones occurring in these USAF aircrew, 446 to 668 of them would be expected to have asymptomatic gallstones. Of these aircrew, 15% to 20% would be expected to have radiopaque gallstones, which would represent 67 to 134 aircrew. With a 0.1% to 0.7% per annum occurrence of onset of severe symptoms in aircrew with asymptomatic gallstones, 0 to 5 aircrew would be expected to become acutely symptomatic. If all of the aircrew were screened using ultrasonography and after a hypothetical maximum of 688 cases had been identified an occupational cholecystectomy were performed, 25 would be expected to have complications and one would be expected to die out of 500 surgical cases.

The risk of a USAF pilot or navigator with asymptomatic cholelithiasis experiencing an acute onset of gallstone-related symptomatology inflight is estimated to be considerably less. Again, using the 1994 aircrew manpower data and the worse case of a 0.7% occurrence for the onset of acute symptoms associated with previously asymp-

tomatic cholelithiasis, up to five aircrew would be expected to experience acute symptomatology at some time during 1994. However, if every aircrew flew and was exposed to 200 to 1,000 flying hours during 1994 (figure 1), 0.1 to 0.6 individuals, or at most one, would be predicted to experience acute symptoms related to gallstones in flight.

sentially nonexistent in USAF aircrew. The surgical morbidity and mortality risk is greater than the flying safety/mission completion risk for USAF aircrew with asymptomatic cholelithiasis. Considering the essentially nonexistent inflight risk and the comparably significant surgical risk, occupational cholecystectomy would not be indicated for USAF pilot and navigator risk modification in this subset of patients.

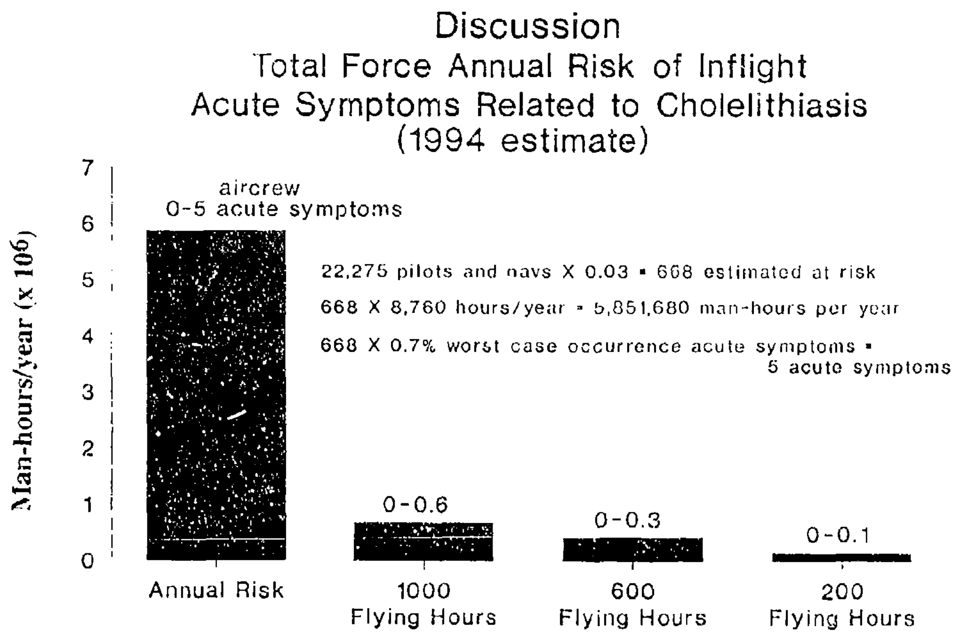

Figure 1 - Predicted Annual Inflight Episodes Per Total Annual Flying Hours (1994)

CONCLUSION

The natural history of cholelithiases in USAF pilots and navigators is more favorable than suggested by clinical literature. The predominately young male USAF aircrew population would be expected to have a lower prevalence of cholelithiasis than the general population. The overall incidence of acute cholecystitis within USAF aircrew would probably not be changed by aeromedical cholecystectomy being performed on incidentally detected asymptomatic cholelithiasis. The inflight risk of experiencing acute symptoms associated with previously asymptomatic cholelithiasis is essentially nonexistent in USAF aircrew.

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CLINICAL BASIS FOR AEROMEDICAL DECISIONS IN AIRCREW HIV POSITIVE

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INTRODUCTION

During the 1980's, HIV infection emerged as a leading cause of death all over the world.
At present, WHO estimates that 13 million men, women and children have been infected with HIV. Each day, an estimated five thousand people are newly infected. By the year 2000 forty million people may be carrying the virus (1).
Obviously, we cannot separate such a global medical problem from the context of the flying community.

From an aeromedical point of view HIV infection presents multiple concerns. Perhaps the most important aspect is the Neurological Symdrome , which can cause sudden incapacitation.
A variety of neurological complications may appear at any time in the disease process, affecting 75 to 90% of HIV positive individuals (2). Perhaps the most dreaded and frightful entity is the "AIDS Dementia Complex (ADC)". The initial manifestations of ADC are subtle and typical of a subcortical dementia with subacute evolution. It is unusual to develop ADC during the initial stages of the disease, as it seems related to the loss of immunologic capability manifested by the CD4 lynmphocyte subset being less than 200 µl (3).

Individuals with such a profound immune system deficit will not be flying, making the classically described ADC a nonfactor with regards to the potential of adversely affecting the performance of flying duties.
However asymptomatic seropositive individuals might be on some type of flying status depending on a particular Air Force's policy of waiver elegibility.

Many studies have been done in order to evaluate any kind of cognitive impairment in otherwise healthy HIV infected individuals. The current literature was summarized by the American Academy of Neurology, who concluded that "at present there is no evidence for an increase of clinically significant neuropsychiatric abnormalities in CDC Group II or Group III HIV-1 seropositive (i.e. otherwise asymptomatic) individuals as compared to HIV-1 seronegative controls" (4).

HIV SCREENING AND THE AIRCREW.

The policy of other nations (i.e. USA) of mandatory HIV antibody testing in the

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military is based on the concern about world wide deployment with limited medical resources, use of a attenuated live virus inmunizations, and the concept of the walking blood bank (5).

Before the policy of universal screening can be implemented, some important points must be addressed:

1. It is important to distinguish screening an asymptomatic, low risk population from diagnostic HIV testing in symptomatic patients who may have AIDS or screening members of high risk groups. In low prevalence areas a substantial proportion of positive tests will be falsely positive. The joint false positive rate of the ELISA and the Western blot tests when performed in series has been estimated to be as high as 1/1250. It is imposible to estimate the economic and social impact of erroneously informing patients that they have antibodies against HIV. Two confirmatory Western blot tests, rather than one, and rigorous quality control measures in the laboratory will reduce this figure to an acceptable 1/135187 (6).

2. A comprehensive program of medical and social support for invididuals confirmed to be HIV positive must be established before the mandatory testing should be undertaken. This way physicians and their test will not appear as merely "Hunters" of the seropositive.

SEROPOSITIVE CANDIDATES/FLYERS

1. Policy of the Spanish Air Force (SAF) is to test all candidates for aircrew duties and any other personnel that could be included in the risk population once interviewed through their physical exam.

2. Every candidate for aircrew duties confirmed HIV positive is rejected.

3. If an aircrewmember is confirmed HIV positive in a periodic physical examination, the aeromedical disposition is to ground the flyer and to start the necessary studies in order to assess the actual state of disease progression. Evaluation includes complete medical history, full physical exam, a CBC, biochemistry, urinalysis, Chest X Ray, Mantoux (5 PPD), Hepatitis B & C, Syphilis, Toxoplasma and Leishmania serologies, CD4 and CD8 (absolute and percentage values), cutaneous immunity test, P24 Antigen, anti -env, anti gag antibodies test.

4. We consider that there is no discussion when the subject is symptomatic or when the surrogate markers of progression of the disease indicate that some form of treatment is needed. Those individuals with any signs of advance in the disease process are uniformly and permanently grounded. However the aeromedical disposition is under full discussion when the subject is asymptomatic and CD4>500 µl.

5. In the context of the SAF, our opinion is that close follow-up, including neuropsychological assesment, necessary imaging techniques and evaluation of the surrogate markers every three to six

months will allow us to maintain the certification of asymptomatic HIV positive individuals with specific restrictions considered on a"case by case" basis.

CONCLUSIONS

There has been appropiate concern regarding HIV infection and its effect on aviation safety. Among reasons cited is the consideration that the nervous system is involved early in HIV infection and that dementia in its early stages may be subtle and difficult to detect, on opinion not currently supported by the medical literature.

Others have felt that seropositivity alone did not constitute an unacceptable risk to aviation safety, suggesting that other criteria be used, such as the development of AIDS related symptoms, or laboratory abnormalities, prior to grounding a flyer.

Discussion and controversy will continue in this area untill specific studies of asymptomatic seropositive individuals' performance in real and simulated flying environments are carried out by the aeromedical community. As the prevalence of this disease continous to grow exponentialy in the general population the answers to this questions will become increasingly more important.

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COLOR VISION ISSUES IN MODERN MILITARY AVIATION
Alternate Title: "THE SEARCH FOR THE ABOMINABLE CONEMAN"

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SUMMARY

Visual information provided to the modern military aircrew member accounts for the preponderance of data contributing to situational awareness. Although long recognized as a critical factor in aviation, as a result of advancing technological developments, color vision is emerging as an ever-increasing critical requirement in modern and future cockpits. Despite that premise, the modern battlefield is characterized by a vast array of technological weaponry that increases the threat to the visual system and dictates effective countermeasures that compromise visual performance in general and color perception in specific. This paper will review the aeromedical basis of color testing developments and issues that effect aeromedical decisions in color standards and performance as they relate to the modern military aircrew member. It will include an update on color vision issues raised by protective equipment such as selective waveband filters that include sunglass materials and laser protective eyewear/visors. Color-related aircraft accident issues will be addressed.

LIST OF ACRONYMS

LEP	laser eye protection
SAM	School of Aerospace Medicine
AO	American Optical
PIP	Pseudoisochromatic plates
FM	Farnsworth-Munsell
CTT	color threshold tester
FALANT	Farnsworth Lantern
R/G	red/green
B/Y	blue/yellow
VASI	Visual Approach Slope Indicator
FLIT	fighter lead-in training
USAF	United Stated Air Force
UPT	undergraduate pilot training

I. INTRODUCTION

The modern combat arena is a multifaceted sophisticated techno-extravaganza. Scientific development of complex weapon systems has advanced almost exponentially. These lethal gizmos produce a kaleidoscopic universe of electronic symbology and information, primarily focused at the human element cradled within the system. Laser technology exploits susceptibilities of that human system. Defensive mechanisms, selected to protect and optimize the human interface use selective waveband filters, themselves inducing additional visual handicaps. The modern cockpit has evolved into a montage of colored symbology and cues presented in a visual blitzkrieg under task-saturated and hostile conditions. At no other time in the history of aviation has any facet of the visual system been more challenged than color discrimination is today. Engineers design multicolored displays hoping to facilitate information transfer

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between the aircraft and its master, but often paradoxically exceed physiological realities. The stakes are, indeed, high; survivability and mission completeness essential, political sensitivities, keen.

This paper addresses relevant color issues in the modern cockpit environment of today and tomorrow. Can we continue to expect pilots harvested from the normal population to visually cope, survive, and optimally couple with weapon systems that rely so heavily on color-based cues and which are then paradoxically degraded further by virtue of required protective equipment? One question emerges that impacts on aeromedical decision-making today and in the future: Does "Superconeman" exist, do we need him, and should we, as aeromedical consultants, embark on a journey in search of an "Abominable Coneman"?

It is appropriate to review the historical role of color vision in aviation and the selection standards that for 75 years have governed our approach to aviation color vision issues.

II. HISTORY OF COLOR VISION STANDARDS IN THE U.S. AIR FORCE

We begin by recalling a profound historical statement: "The proper recognition of color plays an important part in the success of all flyers. On the maps generally used by observers, the woods are green, rivers are blue, roads are yellow, railroads are black, and towns are brown. Skyrockets with a parachute are white, red and green, and cartridges--with and without parachutes--are of similar colors. Bengal flares, which are used in woods and heavy underbrush, are red and white. Aerodromes use red and green or white lights for homecoming planes, while the planes carry a red light on the port side and green light on the starboard side." This description is part of a paragraph taken from Aviation Medicine in the A. E. F., from the chapter "The Eye in Aviation", written in 1919 by Col W. H. Wilmer and Maj Conrad Behrens (1). It contains much that is still important in flying aircraft today. During WW I, medical examiners felt that color vision testing was an important part of the physical examination of applicants for the aviation section of the Signal Corps. Testing for color deficiencies was done by the Jennings Self-Recording Color Test. Instructions were given that stated that if a Jennings test was not available, the medical officer should select a skein of any shade of red or green worsted and have the candidate select in separate piles all skeins containing red or green. If confusion was still present, colored lights at 20 feet should be used as a test before rejecting a candidate (2). It is evident that, even at the very onset, there were color vision testing problems. Between WW I and the onset of WW II, the SAM Department of Ophthalmology at Randolph Field, Texas, carried out a series of tests to detect color blindness. Experimentation was carried on with Holmgren skeins, the Jennings Self-Recording Test, Stillings' PIP and Williams' Lantern Test. It was recommended in 1935 that the Ishihara Test be adopted for color vision testing of aviation candidates (3). When the Ishihara test was first included in the examination, those who failed were rejected, but by 1940, several other tests, such as the Stillings' PIP, Holmgren yarn matching and lantern tests, were also used to examine the extent of color

blindness (4). The authorized tests for central color vision in 1941 were the Ishihara or Stillings' PIP and Holmgren skein of yarn.

During WW II, a large number of studies on color vision were performed at the Army Air Corps SAM at Randolph Field. Most of these were accomplished under the direction of Louise L. Sloan, Ph.D. At the time these studies were initiated in 1942, four tests of color vision were authorized for use by the U.S. Army Air Corps. There were two basic tests--the Ishihara PIP (8th ed.) and the AO PIP--and two adjunct tests--the Holmgren wool test and SAM lantern test. Ability to pass the adjunct tests was used to qualify candidates as "color safe" under certain conditions. Regulations were rather vague; consequently, it was left to the individual examiner to select a testing device and method of scoring to distinguish between those who did and did not meet this criterion. Between 1942 and 1945, numerous tests were investigated at Randolph Field, such as the AO PIP, Rabkin polychromatic plates, SAM anomaloscope, Rand anomaloscope (Bausch and Lomb), Intrasociety Color Console (ISCC), Single Judgment Test, Eastman Hue Discrimination Test, FM 100-Hue Test, Terrain Test, and Peckman Vision Test. Also, a major effort was put forth in testing a number of lanterns; the Canadian Lantern and SAM CTT were the major efforts. The sum of these investigations was that, in 1943, the AO Abridged Set of PIP was selected as the most suitable basic test. This abridged version was composed of 17 tests and 2 demonstration plates. Of the quantitative tests investigated, the SAM CTT was rated the most satisfactory to classify flying personnel (5). These tests continued when the USAF became a separate service in 1947 and culminated in the assembling of the AO 15-Plate Test (14 test plates and 1 demonstration plate) in 1951. This set was adopted in 1953 as the USAF official color vision screening test. It's still used today except that in 1985, the AO plates were purchased by the Richmond Company and are now known as Richmond plates. Dvorine color plates could also be used in place of the AO plates. The Dvorine plates were printed in two volumes in 1944. The second edition, published in 1953 under the title "Dvorine Pseudoisochromatic Plates", also had 14 diagnostic plates and 1 demonstration plate. These plates are still used; however, they are no longer being manufactured (6). Today the only testing charts are the Richmond PIP.

From 1959 through 1984, the AO and Dvorine 15-Plate Tests were used interchangeably and were the first tests administered for aviation candidates. The causes for rejection were 5 or more incorrect responses on either set of plates. However, a test failure using the plates required testing by the SAM CTT. The CTT had 64 presentations; a score of 50 or better was passing (7). The USAF followed the example of the U.S. Navy, allowing mildly color-defectives to enter flying training. The U.S. Navy had used the FALANT to accomplish the same thing.

In 1988, the SAM CTT was removed from the inventory and the FALANT was substituted for the CTT. An aviation candidate who fails the Richmond PIP may still qualify if he passes the FALANT. Table 1 shows a chronological listing of the color vision qualifying tests used by the U.S. Army Air Corps and the USAF (8).

DATE	TESTS
1918	Jennings' Self-Recording Color Test
1935	Ishihara PIP
1941	Ishihara or Stillings' PIP
1942	Ishihara-AO PIP
1943	AO PIP test (17 test plates, 2 demonstration plates) SAM CTT (quantitative test developed)
1953	AO Isochromatic Plate Test (14 test plates, 1 demonstration plate)
1959	Dvorine PIP (14 test plates, 1 demonstration plate)
1959-84	AO and Dvorine for *FC I and IA - SAM CTT if plates failed
1985	Richmond plates replaced AO PIP for FC I and IA
1988	SAM CTT replaced by FALANT; passing the FALANT after PIP failure qualifies for FC I, IA and II

*FC I and IA = pilot (I) and navigator (IA) applicants

Thus, this testing methodology is designed to allow all trichromats and mild anomalous trichromats (R/G) to fly. More severe anomalous trichromats (R/G) and dichromats are not allowed to fly. B/Y assessment is not performed. Can we continue to support existing standards, or has the time come for us to employ a more rigid approach to reduce the impact of color vision deficits in future aviators? A review of modern-era military and civilian aircraft operations reveals that there have been, and continues to be, color-related factors that aggravate, compromise, and complicate flight operations. In some cases, aircraft have been lost. Surprisingly, these incidents have been few. It is highly probable that current color-screening methods have been as effective as anticipated, or perhaps color vision is not as critical as thought. Can these same screening methodologies continue to ensure the safety of our aircrews and mission completion in a color-complicated future? Also, there remain considerable unknowns with respect to causative factors of aircraft accidents and, in the case of retrospective database searches, often there is no stipulation that specifically requires color-vision-related data storage (USAF). We would like to present examples where color deficiencies are known to have played a significant role, either in task complication, a near mishap, or an aircraft accident, each provoking a different thought regarding current policy.

Examples

1. A 24-year-old A-10 pilot with 350 total flying hours was grounded without waiver after evaluation revealed the following data. He failed the FALANT but passed the CTT on initial entry physical exam at the Air Force Academy (AFA). On two reevaluations at the examinee's request, he failed the CTT. He failed the PIP (4/14 correct) and FALANT on 2 of 3 trials during his commissioning physical exam prior to graduating from the AFA. However, records indicated that he was qualified for and entered UPT. The pilot reported that during UPT he could never use the VASI lights on landing approach because he could not discriminate between the different color presentations (red/red = glideslope too low; white/white = glideslope too high; red/white = correct glideslope. Otherwise, neither he nor his instructors reported any difficulties during UPT. He went on to FLIT and flew the T-38. On one flight, a group of tan-colored coyotes crossing

the runway were unobserved by the pilot and his instructor pilot took the aircraft controls to avoid striking the animals. The pilot completed FLIT with no other difficulties. He then began training in the A-10. From the beginning of training, he noted difficulty identifying other green-colored A-10s flying at low level over green terrain. He also reported having difficulty with crossover turns, night refueling, rejoins in close formation, low-level formation flying, and night flying, and continued difficulty with the VASI light system. He reported that he was uncertain whether his perceived difficulties were a result of his color deficit or were normal problems experienced by most pilots. After reporting to his first A-10 squadron, his concerns led him to the flight surgeon, stating that he felt he was endangering himself and others while flying. He failed both the PIP and FALANT color tests. Extensive evaluation found severe protanopia, presumably congenital; however, a progressive cone dystrophy could not be ruled out at that time. Subsequent retesting has been stable to date, but he was permanently grounded because of safety concerns.

2. A 45-year-old navigator/EWO with 3,500 flying hours was diagnosed with adult-onset foveomacular vitelliform dystrophy. This defect began much earlier in life, but wasn't uncovered until he developed a loss of visual acuity O.D. because color plates and FALANT did not identify his acquired B/Y defect. A thorough evaluation revealed a moderate tritan (B/Y) color defect, most likely associated with the foveomacular vitelliform dystrophy. Since current screening tests only detect R/G defects, the EWO was able to pass the current standard PIP and FALANT tests. His defect was regarded to be operationally significant, however, because current color-enhanced radar uses B/Y symbology.

3. An F-4 pilot was performing clear-weather, night touch-and-go's during airfield aircraft carrier landing practice prior to transitioning to carrier duty. Two other aircraft were in a 2-ship formation in an authorized pattern above the airfield and operating on a different radio frequency than the F-4 pilot, as was customary. The F-4 pilot was departing from the airfield when he observed diverging aircraft wingtip lights. He believed the lights to be from one aircraft instead of two and, since they were diverging, he perceived the aircraft to be on a collision vector. He responded by cutting back power to avoid a perceived impending collision, resulting in an unrecoverable stall. Both crewmembers safely ejected; the F-4 was destroyed. The investigation board determined that the F-4 pilot was never in danger of a collision and that the other aircraft were properly positioned and not at fault. The mishap pilot admitted that he had a longstanding color vision deficit and was never able to discriminate between the different colored lights on aircraft wingtips! He had failed the FALANT on initial flight physical exam, but "passed" on retesting. He stated that he was able to pass the color tests only by cheating. Following the mishap, he failed the FALANT test. After further evaluation, he was found to have a congenital deuteranomalous defect. The investigation board determined that his color vision deficit was a contributing factor because he could not discrimi-

nate between different colored wingtip lights, leading to the misperception that there was one aircraft on a collision course in the night sky instead of two separating aircraft in a normal approach pattern.

Current color screening methodology is primarily based on the historical requirement of red/green/white discrimination within a male population and, to a degree, is based on incomplete and faultily-derived information. Retesting for R/G deficiencies at increasingly infrequent intervals--or at all--does not incorporate the capability to survey for acquired color deficiencies. Infrequent monitoring for change, as well as creative testing techniques (often with the direct help of a sympathetic test examiner or "color assistant" who may indirectly be coaxed to provide additional hints), contributes to a less than perfect color screening methodology. Similarly, initial testing results, obtained once, are often historically referenced in an aviator's record without retesting or considering acquired change.

Screening efforts, therefore, have been directed toward identifying those individuals who would be unable to differentiate operationally between red, green and white lights. The incidence of sex-linked congenital defects in the male population has been assessed at 8-9%. This figure can be further broken down into deuteranomaly at 5-6% (green-cone-weak anomalous trichromat); protanomaly at 1% (red-cone-weak anomalous trichromat); deuteranopia at 1% (green-cone-absent dichromat); and protanopia at 1% (red-cone-absent dichromat). The incidence in the female population is not as well established but is estimated to be almost 0.1-0.3%. Color performance in females has been grossly overlooked because of the inherent and disproportionate nature of the sex-linked association in males, the primary aircrew pool in the past. The incidence of B/Y or tritan defects is regarded to be quite low, in the range of 0.002-.007% of males. The exact incidence of B/Y defects within the male population is unknown and should be regarded falsely low for a variety of reasons, including the fact that B/Y defects are not routinely screened for by common color screening tests. Even the fundamental research by W. E. Wright, who screened for B/Y defects via a B/Y test plate produced in LIFE magazine (British) in 1970, was wrought with considerable underreporting biases. Even less is known about B/Y defects in females. The sex-linked nature of B/Y defects has not been established, appearing to be a more autosomal deficit, and therefore as likely to express itself in the female population as in the male.

Acquired color vision deficits can be produced by a number of pathophysiological mechanisms. These include primary retinal diseases such as idiopathic central serous chorioretinopathy, retinitis pigmentosa, hereditary and acquired maculopathies, glaucoma, optic neuritis, toxic forms and drug-induced forms. For example, antimalarials have been linked to acquired color vision defects. The onset of acquired defects is not always preceded by a decrease in visual acuity or other performance decrement that would alert either the aircrew member or the flight surgeon. These differences can be used clinically to help ascertain the potential etiology of a color vision

defect, especially in the absence of historical test scores.

Table 2 summarizes the characteristics of congenital versus acquired color vision defects.

in the absence of any color-neutral, "see it no matter what" design redundancies, you have created a potential formula for disaster in color-normals and almost certainly in color-abnormals.

TABLE 2.

CONGENITAL DEFECTS	ACQUIRED DEFECTS
Color loss in specific spectral region	Often no clear-cut area of discrimination loss
Less marked dependence of CV* on target size and illuminance	Marked dependence of CV on target size and illuminance
Characteristic results obtained on various clinical CV tests	Conflicting or variable results on clinical CV tests
Many object colors are named correctly or predictable errors are made	Some object colors are named incorrectly
Both eyes equally affected	Eyes affected asymmetrically
Usually no other visual complaint	May have decreased acuity and field loss
Defect is stable	Defect is labile, with progression and regression

*CV = color vision

It is particularly relevant aeromedically to realize that current selective waveband filters, ranging from the high-contrast yellow visor to the more deeply pigmented dye formulations used in LEP devices, ironically induce complex color vision deficits in color-normal individuals that closely parallel acquired defects such as are seen in ocular or optic nerve disease. These devices induce complex and profound R/G and B/Y color deficits in known color-normals, but are unpredictable and have as yet undetermined impact on color-weak or frankly color-abnormal aircrew. When you overlay significant induced color loss with full visual spectral electronic displays,

At least one midair collision between aircraft engaged in air-to-air training was attributed to factors induced by a combination of yellow visor and green sunglasses worn by the attacking pilot.

III. COLOR TESTS AND METHODOLOGY

R/G Testing. Common test devices and methodology fall into four basic categories: plate, arrangement, lantern, and anomaloscopic tests.

Plate tests depend on confusion lines to elicit their effects. They require the proper color temperature illuminant; otherwise, the basic design premise of the

test is invalidated and the results become erroneous. The PIP rely on identification of a colored symbol embedded in a color-confusion or gray background; the background and symbol are composed of confusion colors that appear clearly to color-normals but seem identical (confused) to color-defectives. These screening tests identify those individuals with congenital R/G color defects and are based either on theoretical properties of the color vision system, or on statistical data about confusion colors from known color-defectives. Protanopes confuse certain greens with reds, and deuteranopes confuse other greens with purple. Examples of such tests are the Ishihara, Dvorine, AO, Richmond, AO Hardy-Rand-Rittler, and Tokyo Medical College. Advantages of these tests are they are simple, easy to administer and inexpensive, and can be used with illiterates and young children. The tests generally do well compared with the anomaloscope, showing agreement ranges of 0.95 or higher. No calibration is required by the user. Disadvantages are the required use of a special illuminant C; the presentation of confusion colors, which may be difficult to duplicate through the printing process; and, because of eye pigmentation or lens coloration, the selected colors may not be correct for a specific individual. The plates may be degraded by fingerprints, dust, and excessive light exposure, and must be kept in a case when not in use. The test should be presented monocularly. The plates should also have their order rearranged to preclude sequence memorization that can be shared between test subjects.

Arrangement tests require the subject to arrange color samples by similarity in a series, often a color circle. The caps are numbered on the back and can be moved freely during testing. Several testing strategies are available and include color confusion, hue discrimination, and evaluation of neutral zones (colors seen as gray). Examples of these tests are the FM-100 (hue discrimination), D-15 (color confusion), desaturated D-15 (color confusion), and the Lanthony New Color Test (color confusion and neutral zones). Advantages of these tests are that they are easy to administer and can be used with naive subjects. The FM-100 and D-15 discriminate between protan, deutan and tritan defects, based on axes of confusion. The D-15 does not discriminate anomalous trichromats. The FM-100 is quantitative, with a long history of use and population bases for comparisons in hereditary and acquired conditions. The validity of the tests varies; the D-15 shows agreements with the anomaloscope of between 0.73-1.00. The desaturated D-15 has not accumulated enough data to allow appropriate comparisons. However, 98% of dichromats and 70% of anomalous trichromats will fail the desaturated test. The FM-100 may be statistically assessed at $P<0.05$ or 0.01. Scores may vary with age, test experience, and wavelength discrimination function. The Lanthony test is still under evaluation. It is designed for acquired defects and, therefore, a plethora of test conditions must be considered. All of these tests require manual dexterity and may be difficult for some patients. Pigments may be damaged by fingerprints; therefore, gloves should be worn by test subjects. Spectral quality of the light source illuminating the plates is critical; the caps of the D-15 and FM-100 tests are made from Munsell colors for which CIE specification is

available only under illuminant C. No calibration is required.

Lantern tests were conceived as occupational tests to evaluate red/green/white discrimination in seamen, railway personnel, and airline pilots, in order to assess their ability to discriminate navigation aids and signals. Correct color recognition is the important variable. The value of lantern tests is their ability to simulate the actual work environment. They do not specifically identify types of color defects. They were designed to screen out individuals who cannot see red, green and white occupationally, and will pass color-normals and color-weak R/G defectives. The expectation is that color defectives who pass a lantern test will perform as well as color-normals in their occupation. The most representative device, and the only one readily available, is the FALANT. This test uses red, green and white lights that are confused by people with more severe color defects and does not attempt to mimic navigational aids. The assumption is that if an observer can see the lights that color-defectives can't see, then they should certainly see those colors that color-defectives don't fail. A design feature of this test permits 30% of color-defectives to pass. The validity of these tests, compared to the anomaloscope, is very limited, so agreement factors have not been published. Test advantages are the device is self-luminous, so it may be used in normal room light; random presentation is easy to accomplish; and administration and scoring do not require highly trained personnel. Availability varies, being an "off-and-on" phenomenon. Several creative schemes have been devised to "game" this test or "con" the examiner, one example resulting in an aircraft loss. No calibration or maintenance of the lantern is required, and CIE chromaticity specifications are available.

The anomaloscope is the gold standard device of color vision testing and depends on the Rayleigh equation. The test subject is asked to match a yellow light by mixing varying amounts of red and green. The amount of red and green selected is the Rayleigh result. Normals match pure yellow (589 nm) with an equal mixture of pure red (670 nm) and green (545 nm). Protanomalous trichromats require more red in the mixture and deuteranomalous trichromats more green to make up for their inherent deficiencies in a particular cone class. Protanopic or deuteranopic dichromats will accept a wide range of R/G mixtures to "match" yellow, because they match brightness and not color. This test has a long and well-established history and is the definitive test for R/G color vision. It is used to validate other color vision tests and requires a spectroscope for calibration. The apparatus is expensive, requires experienced examiner skills, will not tolerate rough handling, and is not a readily available screening tool. The Nagel anomaloscope is the only device that may be used to classify genetic R/G color vision defects. Several new electronic versions that include B/Y testing are currently available and under evaluation.

Plate and arrangement tests are designed to identify individuals who may need more extensive color testing. They do not diagnose a specific color defect. A test subject who passes the plate test for R/G deficits is regarded as

color-normal for R/G only. Plate tests are not quantitative but should be regarded as pass/fail, requiring further evaluation with other sophisticated testing to evaluate the color deficit. Individual laboratories need to establish their own test battery to satisfy their needs with respect to R/G defectives. A validated plate test and the FALANT are both effective R/G screeners. In combination, they even improve upon their validity as opposed to one test employed alone.

B/Y Testing. Because of the apparent significantly lower incidence of congenital B/Y defectives and the traditional R/G aviation world, current color screening methodology excludes this category. Of questionable historical validity, we believe that this is no longer the case, and therefore B/Y should be evaluated as well, for screening congenital and acquired deficiencies. We maintain that, in the modern cockpit of today and tomorrow, the importance of B/Y discrimination has been underscored and needs consideration in order to maximize this aspect of the aviator's visual system. Given the complicated induced color defects imposed with LEP, extremely task-saturated multispectral electronic displays, and the need to avoid limiting design evolution that could capitalize on the virtues of a truly color-normal visual system, we believe it is time to screen and monitor for B/Y defects. Several tests currently are available to assess this ability; however, many remain elusive and, at the present time, are not readily available. This is not to say that, with proper support, they could not become so. Certainly, the FM-100 and D-15 evaluate this performance element; however, they are not ideal screeners. These tests were not optimized to assess this performance and do not identify severe anomalous trichromats. The Pickford-Nicolson anomaloscope and the AO Hardy-Rand-Rittler PIP are no longer available commercially, but were employed in the past to assess B/Y deficits. The Farnsworth F2 plate remains available on a limited basis to color researchers, but could easily be made more available as a screening plate. It can be produced inexpensively and could be included in the standard PIP test to allow screening for B/Y defects. Failing this test would be either disqualifying or indicate further definitive evaluation. The F2 plate is currently available through the Naval Submarine Medical Research Laboratory, Groton, Connecticut.

If our color logic is acceptable, adding the Farnsworth F2 plate would provide a more optimal screening strategy. If acquisition of this type of plate fails, then the D-15 could be employed. Although somewhat more time-consuming and perhaps more redundant, the D-15 will test for B/Y dichromats but not for B/Y trichromats; it's therefore less than perfect for this purpose.

Development of a standard PIP Part 2 test offers potentially a cost-effective alternative to the F2 plate. This test was developed in 1983, basically as an acquired B/Y color-vision tester, but has not so far been employed as a screening test because of our fundamental approach concentrating on R/G deficits. It is a readily available, inexpensive ($57 U.S., Igaku-Shoin Ltd, 1 Madison Ave, New York 10010) test designed to identify

acquired B/Y deficits. Its ability to identify congenital B/Y deficits warrants further investigation and may offer an effective alternative to the F2 once validated from this perspective in the future. In the meantime, it is an effective evaluation tool in the evaluation of B/Y deficiency.

A more expensive approach would be to design an operational color screening cockpit employing all the latest electronic displays in a real-world simulation test. Obviously, standardization of display symbology would facilitate this process, but may be unrealistic operationally. Certainly an effective and practical compromise could eventually be reached. Fundamentally, and in the meantime, we believe that inexpensive testing methodologies to locate "Super Coneman" currently exist.

IV. MODERN AVIATION COLOR VISION ISSUES

It is appropriate to expand consideration of color vision issues into the arena of the modern cockpit and beyond, in the hope of stimulating imaginations and concerns in support of more complete and stringent color testing. One has to only look back 20 years in cockpit design to compare current "old" operational aircraft with "new" aircraft to appreciate the way in which cockpit designs are evolving. A valid question--painful for some--might be "Will the manned part of the system evolve with it?"

Selective waveband filters. The all-glass cockpit produces a staggering amount of predominantly color-coded visual information for artistic, if not functional, reasons. Redundant symbology and consideration of the impact of selective waveband filters on discriminating this symbology have either been totally excluded, partially accommodated, or realized after the fact. Clearly, red, green and white signals have become passe and boring. Current electronic displays employ a vast color pallette, seemingly attempting to use as many pixels of individual colors as possible. Considering the eye can recognize 4,000 individual colors, the possibilities are endless. All this colormania has been done without regard for color-defectives. In fact, an aviator had better be a "Super Coneman" to fully appreciate the electronic, multidimensional, full-spectrum, technicolor extravaganza in the cockpit. When LEP enters the picture operationally, things unintentionally begin disappearing from this visual environment. Certain colored symbology sizes become difficult to see through LEP visors, requiring doubling their size to ensure 100% recognition. Redundant, color-independent symbology is not always present, but, without doubt, should be. For the "operationally induced" color-impaired, it is imperative that "switchology" exist on current displays to neutralize the impact of LEP, but such design features complicate and add to the cost of the equipment. However, there appears to be no alternative if we are to adequately protect our aircrew from laser threats. Since hostile lasers remain agile with respect to wavelength and a single defensive solution elusive, this compromise of color performance is likely to remain an irritating cost of doing business. Fundamentally, in order to predict the impact of a particular LEP on an aviator, it is beneficial for vision scientists and engineers to

understand the impact of a particular visor on the aircrew population. There is no question that the impact on color-normals is profound. The inclusion of color-weak or color-abnormal aviators within this population and the lack of information to date on the impact of these devices on this subset, complicates this matter considerably. In addition to an unpredictable effect on those aircrew, it requires complicated studies to ascertain the full extent of such devices on color-abnormals. Thus, there remains the seemingly insurmountable task of protecting aircrew from agile laser threats and still ensuring the unaltered full potential of information transfer through existing and future aircraft. A laser-induced reality may require a return to monochromatic displays or removing the pilot. Some aircraft employ color contour map-display systems that are presented visually to aircrew through various means. These displays must be modified to accommodate or neutralize the impact of LEP on the information they present. Since only one visor can be worn at a time, it is a challenge to match the appropriate visor to the threat environment. Given agile laser threats, it is likely that this selection will more likely be wrong than right. We can only hope that evolving technologies will solve this problem.

Air-to-Ground Operations. Despite exclusive initial night strikes using night-vision devices (NVDs), Desert Storm demonstrated that surgical daylight strikes continued to be--and are likely to be more so in the future--a prominent part of tactical air operations. In this context, map reading tasks, visual target confirmation, and smoke marker detection are greatly enhanced, if not totally dependent upon, an intact color vision system. These tasks become extremely difficult, if not impossible, through LEP devices, and have a variable impact on color-normals and an unpredictable one on color-abnormals. Although some selective waveband filters can enhance detection of a particular color range, this advantage is accompanied by a loss of discriminatory ability in other color ranges and an overall reduction of luminance, inducing a new challenge. This new, altered color world would have to be "learned" rapidly, often under duress; information processing time would be increased and a color-weak individual's performance time would be degraded disproportionately.

Naval air operations present additional unique and critical color-recognition tasks. These tasks require exquisite choreography between aircrew and deck crew who wear color-coded ensembles to identify their flight deck responsibilities. Extremely hazardous, time-critical night carrier landings, although not totally dependent on color discrimination because of automatic landing light systems, are greatly improved by the aviator's ability to discriminate color cues rapidly. Colored lights are important to delineate aircraft carrier superstructure and orientation during night recoveries. This is not to say that night landings cannot be accomplished by color-weak individuals, but this extremely critical phase of flight, characterized by a very narrow window of opportunity and a paucity of alternatives, is greatly enhanced by intact color discrimination.

Air-to-Air Operations. Despite technological advances in long-

range missile intercepts, visual identification of potential hostile aircraft in politically sensitive situations, and the fact that not all missiles hit their intended target (only 20% in actual combat) still dictate the need for close-range dog-fighting capability with its strong reliance on the air-craft's cannon. The tactical offensive employment of airborne lasers to dazzle or incapacitate an adversary requires the dependence on LEP in the air-to-air arena in the future. A pilot's ability to discriminate adversarial aircraft close in against varying color contrasts despite creative camouflage schemes make this task even more difficult through LEP. In some cases, neutral gray aircraft against a low-contrast surround appear invisible through certain visors, not to mention that they are extremely difficult to see with the naked eye alone. Recent military operations have been critically linked to successful day and night refueling operations. Although a tanker's refueling light tracks employ redundant symbology and only red, green and white lights, blue basket markings on certain aircraft add another dimension. Throw in a requirement for LEP because of the proximity of hostilities to refueling operations and the fatigue from repetitive night taskings, and it can be quickly appreciated how color serves to reduce the stress and difficulty associated with such tasks.

Night Vision Devices (NVDs). The integration of NVDs in air operations has introduced a plethora of new physiologic and equipment interface issues. In effect, NVDs may be thought of in the context of biologic coupling, introducing a complex blend of aerovisual and engineering factors. A great deal has been written regarding the use of NVDs by aircrew; however, we still are relatively naive in such issues as NVD performance nomograms and visual standards, the impact of NVD performance as a function of ocular pathology, physiologic/optical interphasing and other essential NVD neurobiological coupling issues such as color perception. At present, the performance of aircrew with NVDs with respect to an underlying color deficiency has not been evaluated, although studies have been proposed. The emission maximum for the generic night vision goggles (NVG) is 530 nm; the wavelength maximums for red and green cones are 546 and 571 nm, respectively. Thus, it appears that neither cone system is optimally stimulated and can be concluded that the chromatic system is not well coupled to these devices. It seems intuitive that engineering a phosphor's emission characteristics to match the retinal sensitivity of the operator is simpler than any other proposed solution. The impact of any existing color deficiency, be it congenital or acquired, on an individual's ability to optimally use NVDs remains undetermined. As greater reliance is placed on NVDs, better neurobiologic coupling in color-normal individuals is required, and standards must be determined for color-weak individuals to ensure there is no performance degradation with these severely visual-tasking devices. This issue raises a potential disconnect to be avoided or engineered out of the system until studies permit a better understanding of NVD color coupling in color-normals and color-weak/abnormals. How much simpler it would be to establish one category of super aviator, "Super Coneman", and neurobiologically couple the NVD without having to consider

a multitude of biological subsets in the process.

Chromatic Contrast. The detection of sharp edges in a vernier acuity task (hyperacuity) has traditionally been thought to be a product of the luminance system. It is now known to be influenced by color. In a simple situation, suppose two green bars in a red surround provide a vernier (offset) target. If the bars are isoluminant (brightness match), there is a 70% chromatically determined loss of acuity. These sorts of spatial-chromatic interactions must be understood and exploited in the cockpit. Traditional contrast sensitivity, used to accurately evaluate pattern vision, principally uses the brightness pathway. Homochromatic, isoluminant gratings (e.g., alternating red and red stripes) have no visible boundaries. Heterochromatic, isoluminant gratings (alternating red and green stripes) have boundaries that may only arise from the chromatic system, because there is no luminance difference; that is, there is chromatic contrast. This observation has created a new research area relevant to display technology and other aspects of color perception. Luminance patterns and chromatic patterns interact in several ways. Two major effects occur: facilitation and attenuation. The interactions are spatial frequency and wavelength dependent. These sorts of data begin to approximate the real world (cockpit). There is further evidence to support the notion that spatial localization is dependent upon color and luminance contrast. Color can support binocular fusion and color targets may be fused in the context of rivalrous luminance information, just as luminance contrast targets may be fused in the presence of rivalrous color information. Finally, stereopsis for chromatic contrast targets can be eliminated with suitable luminance contrast. Clearly, stereopsis may be manipulated, enhanced, masked, attenuated, etc., resulting in a range of control of stereopsis that heretofore has not been possible. This concept can be regarded as synthetic stereopsis. This manipulation, optimally intended to alter, highlight, attenuate or illuminate information presented in the cockpit, may play a role in future cockpits, especially if virtual reality continues to evolve. It will greatly enhance engineering development and the predicted impact from this type of technology if the pool of aviators share a common and intact normal color visual system. The process of understanding spatial chromatic interactions has just begun and deserves serious attention in those situations that involve biologic coupling of the aviator with cockpit displays, especially in hostile en ments that seem to argue virtual cockpit approach

Virtual Reality. One pr solution to the agile th environment in future ai ations is virtual realit seems impossible to prote aircrew and harden assort optical sensors from all th illusive and dynamic laser threats. "Virtually impossible solution + emerging realities = virtual reality." Although reactive canopies and visors may play a role, the threat environment is so rich and includes so many other threat wavelengths that virtual reality cockpits propose a valid approach to minimizing the impact of such threats. This is an exceedingly complex challenge, and new physiologic problems will certainly arise as this technology matures and

is integrated into weapon systems. Nonetheless, there appear to be significant benefits associated with this approach. An alternative solution proposes removal of the biological component of the weapon system altogether, but for the foreseeable future, this would be regarded as an unrealistic approach, unappealing to enthusiasts, even if predicated on fertile technical merit. The ability to exploit color physics and physiological issues is bounded only by imagination and biological limitations. Ideally, freelance engineering without the encumbrances of limitations secondary to color vision deficits fundamentally and logically warrants support. Should a potential technological development in this area be subjected to premature demise from unnecessary physiological handicaps? Or not developed because of an unpredictable impact when coupled biologically? It seems scientifically unfair to penalize creativity by having to deal with less than optimum human visual systems. "Super Coneman" would be free to conquer his "Color Metropolis" unencumbered by any kryptonite-like weaknesses. Synthetic stereopsis, color contrast, and color stereopsis are some of the emerging color vision principles that need to be fully exploited in the virtual realm before being discarded or lost.

Color Testing Realities. Assessment of an aviator's color performance has often been compromised by basic breaches of testing principles. For example, the wrong illuminant invalidates plate and arrangement tests and contributes to a potentially erroneous passing score. This error, or any initially acquired faulty information, is compounded in the absence or infrequent requirement to reassess this performance. Dependence upon a historically referenced, previously passed qualifying test forgoes the possibility of validation and monitoring for acquired color deficiencies and inappropriately commits a prospective aviator into an ever-increasingly complex color world. Retesting policy regarding color performance varies and often a historically referenced test score suffices in lieu of retesting. Creative gaming techniques, to include memorization, sharing answers, and more elaborate schema to assure a passing score, have all been employed successfully in the past. An example of an aircraft lost to this phenomenon was given earlier. It is not good policy for the aerovisual scientist to be adversarial to prospective and trained aviators, but it is our responsibility to ensure that tests are administered properly and that we eliminate those candidates that are likely to be visually compromised. The "color assistant" phenomenon during color testing runs the full spectrum, from outright sympathetic data entry to compromised testing technique to disinterest or lack of understanding of the significance of responses.

Regardless, performance assessments based on erroneous information can be improperly carried throughout an aviator's career. Acquired color deficiencies can be elusive and are not always associated with other warning signs such as reduced acuity. Reducing the routine monitoring requirement is therefore fundamentally flawed and does not identify an impaired aviator within the color-task-saturated environment of today's and tomorrow's aircraft.

V. SUPERCONEMAN

It appears, given both real and perhaps some conjectural issues, that the argument supporting the search for "Super Coneman" exists now and will have only greater relevance in the future, assuming that humans continue to be coupled with aircraft. The fact is that "Super Coneman" exists now; he's called color-normal. The color world is polydimensional, but our current mode of testing color is based on a unidimensional approach. There are interactions between the chromatic spatial system and the achromatic spatial system such that screening for color capability alone may be misleading in terms of occupational needs and standards, often the basis for color tests in the past. Color anomalies have only been marginally linked to actual "real-world" color performance, and better delineation seems necessary. The color world of the future will need to be understood in the context of interactions of the color system with other aspects of vision, to capitalize on emerging technologies and future cockpits.

Two alternative approaches are possible: one is to promote more extensive screening for preexisting color pathology, coupled with frequent reevaluation, and the other is to continue business as usual and minimize the impact of color-related tasking. The former can be accomplished by more comprehensive visual screening, to include B/Y assessment, whereas the latter accepts a handicap and requires engineered color-independent solutions. The impact of color can be minimized in displays by programming and designing in a switchable, color-neutral mode to employ redundant symbology visible through any present and future LEP or filters, or to maintain a color-neutral approach (in essence a return to black and white electronic displays) wherever possible. Perhaps the ultimate expression of this approach would be to design us completely out of the cockpit, or in the meantime, optimize the biological coupling between display design and known color issues and to embrace color-defectives as well. The first approach maximizes the impact of color discrimination by advocating stricter color standards ("Super Coneman"), and maximizes exploitation of emerging color technologies such as synthetic stereopsis, chromatic contrast and other enhancements yet to evolve. The feasibility of embracing a more stringent approach can be done effectively and with acceptable cost, especially if candidate screening is only accomplished at several centers.

Plate and arrangement tests are designed to simply screen individuals who may need more extensive color testing. Adding to existing plate or lantern methods the ability to assess B/Y performance and to support a program of more frequent testing, supported by appropriate disqualification regulations, will ensure a color-normal aviator pool---one that will have a predictable impact from today's and tomorrow's optical devices and aids--that correlates with laboratory studies and predictably extrapolates to the entire flying pool. This pool would facilitate engineering options and biologic coupling. It would be a pool whose visual tasks and cockpit performance would be enhanced by the color vision system and not penalized by it, thereby negating effective use of that information during a critical phase of flight.

In the final analysis, individual countries will establish an appropriate battery of tests to satisfy their needs. Political realities, however, may alter a pure approach. Today's world of kaleidoscopic color cockpits and tasks, overshadowed by a military drawdown and pilot reductions, seems to echo an opportunity to reduce the pool of candidates to only the very best, in this case, "Super Coneman". This approach will ensure that, to the limits of our ability, we optimally, perhaps synergistically, couple the biologic component to the airframe well into the 21st century, or at least for as long as we continue to sit on a rocket, racing through space, with our hair on fire.

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PHOTOREFRACTIVE KERATECTOMY (PRK) IN THE MILITARY AVIATOR: AN AEROMEDICAL EXPOSE

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SUMMARY

Refractive surgery to correct rehabilitate refractive errors of the eye continues to evolve at a significant pace and is here to stay. The surgical manipulation of the cornea by carefully planned incisions, as in radial keratotomy, represented the first technological procedure to evolve for the correction of ametropia and is an area of continued active development and improvement. More recently, photorefractive keratectomy (PRK) using laser technology to ablate and recontour the corneal surface has emerged as a viable modality. This paper explores the aeromedical factors surrounding this new revolutionary procedure and discusses the issues relevant to evaluating its applicability to the modern aviator as well as reviewing results of the latest clinical trials currently in progress. The goal is to provide the aeromedical community with the fundamental information required to formulate aeromedical decision- and policy-making in regard to a new procedure that is certain to have tremendous impact on future aircrew candidates.

LIST OF ACRONYMS

PRK	photorefractive keratectomy
RK	radial keratotomy
UV	ultraviolet radiation
UVC	short wavelength UV less than 300 nm
nm	nanometer
D	diopters of refractive power
eV	electron volts
VA	visual acuity
BVA	best (corrected) visual acuity
IOL	Intraocular lens

I. INTRODUCTION

Surgical intervention to alter the optical refractive state of the eye is known as refractive surgery. Current procedures have evolved in an attempt to permanently correct myopia (nearsightedness) and, to a lesser extent, in less commonly expressed refractive problems such as excessive astigmatism and hyperopia (farsightedness). Universal acceptance of such a procedure will depend on its success, predictability, stability and safety. A listing of applied surgical techniques to date is as follows:

A. Radial keratotomy (RK)
   1. Hand-made incisions (RK)
   2. Laser incisions (LRK)
B. Epikeratophakia (EPI)
C. Thermokeratoplasty (TK)
D. Laser thermokeratoplasty (LTK)
E. Myopic keratomileusis (MKM)
   1. Manual
   2. Automated lamellar keratoplasty or keratomileusis (ALK)
F. Laser ablation
   1. Corneal surface ablation - PRK with or without erodible mask

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2. Intrastromal ablation (ISA)

G. Myopic intraocular lenses (MIOL)
H. Synthetic corneal inlays
I. Laser-adjustable synthetic epikeratophakia (LASE)

Each of these procedures will be described briefly to enhance our background understanding and to differentiate them from the subject of this expose, PRK. Unquestionably, the evolution and application of laser energy to alter the shape of the eye is an exciting and promising technological development of major significance to medical science and the "war" on myopia. Corneal surface ablation that alters the shape of the cornea using excimer laser technology (PRK) currently represents the most common laser procedure to evolve--one that has attracted considerable international attention, and with it the hopes of ophthalmic surgeons and many myopes.

<u>Refractive Surgical Procedures</u>

Radial keratotomy (RK): In this procedure, the surgeon makes between 4 and 16 radial incisions extending through 90% of the corneal thickness and running from the edge of the optical zone to the corneal periphery (limbus) to flatten the corneal surface. These incisions can be made either by a surgical knife or, more recently, by a surgical laser. Considerable international experience has accumulated with standard, hand-made RK; the laser variant appears to be less optimal. RK has been practiced for a number of years, and although it continues to evolve technologically, it may have reached its clinical zenith. It remains a popular surgical procedure to myopes despite some potential drawbacks.

Epikeratophakia (EPI): This procedure involves the removal of a portion of the central cornea, which is discarded and replaced with a specially contoured implant, made from either a donor cornea or synthetic materials. EPI has limited application; it is primarily used for the optical correction of high degrees of hyperopia such as in aphakia (post-cataract surgery). It is a specialized procedure, performed by a small number of surgeons in a very limited number of cases.

Thermokeratoplasty (TK/LTK): The application of heat to the corneal surface to induce a change in corneal contour, can be achieved with cautery probes or using laser energy (i.e., infrared HOLMIUM laser). It has been used primarily in hyperopia, and although manual application procedures have waned, there is a current resurgence of this technique, rekindled by new applied laser technology.

Myopic keratomileusis (MKM): In this procedure, also referred to as epikeratoplasty, a portion of the central cornea is removed and frozen, lathe cut to recontour, then sutured back onto the original site, resulting in an altered corneal curvature and a new refractive power in the cornea. Recent developments, including enhanced control by microtome automation, are being investigated in a new procedure known as automated lamellar keratoplasty (ALK). This is a complex procedure; in its present form, ALK has limited application, unless techniques evolve to permit greater universality. At present, it is used for high degrees of myopia (up to -30 D), with limited application in the general population of myopes.

Myopic intraocular lenses (MIOL): In this procedure, a myopic anterior chamber IOL is implanted to correct preexisting myopia. It is a relatively new, evolving intraocular surgical procedure with limited clinical experience and application.

Synthetic corneal inlays: In the synthetic corneal inlay procedure, an intrastromal corneal ring made of polysulfone or hydrogel is implanted to alter the anterior corneal curvature. It's a new procedure, currently under technical development.

Laser-adjustable synthetic epikeratophakia (LASE): This procedure employs a collagen exoplant previously sculpted by laser energy to a desired shape and power and attached to the eye. It is a new procedure and has had limited studies to date.

Laser Intrastromal ablation (ISA): In ISA, laser energy is applied directly to corneal stromal tissue. Theoretically, its premise is to collapse or flatten the corneal surface by selectively destroying deeper portions of the underlying supporting corneal stroma, to avoid potential problems associated with removing superficial corneal layers. ISA is an emerging procedure with technical merit and potential universal applications.

Laser surface ablation (PRK): In this procedure, the surgeon uses laser energy to create a central corneal plateau or flattening that reduces the plus refractive power of the cornea. Representing, overwhelmingly, the most common form of laser ablative surgery to date, PRK is considerably advanced in its clinical application internationally; it is the focus of this paper.

II. PRK

In PRK, the ophthalmic surgeon uses the excimer laser to alter (flatten) the corneal contour. It employs 193 nm UVC light, emitted from an excited dimer ("exc-imer") of argon fluoride (ArF). Selection of this wavelength was based on intended effect, predictability, associated complications, and the impact on surrounding corneal tissue. PRK has been used in both human and animal studies since 1986, with an estimated 70,000 human procedures already performed using systems made by 5 manufacturers. The procedure depends on the photoablative effects of high-energy UVC which causes ultrafast vaporization of the cornea by direct photochemical disruption of molecular bonds from photic, photothermal and photomechanical mechanisms. Two laws of physics applicable to PRK are the Grotthus-Draper Law, which states that light must be absorbed by a molecule before a photochemical effect can occur, and the Stark-Einstein Law, which states that the absorption of only one photon is required to affect one molecule. Infrared radiation induces molecular rotational and vibrational changes and is associated with voltages in the 0.01-1.0 eV range. UV and visible wavelengths are associated with higher energy and induce electron changes that involve excitation of valence electrons at levels below 3.0 eV, chemical bond breakage in ranges of 3.0-6.0 eV, or complete ionization and bond breakage at energy levels greater than 6.0 eV. UVC energy levels (6.4 eV) used by the excimer laser result in the removal (vaporization) of a central zone of corneal tissue with, theoretically, minimal or acceptable impact on the surrounding ocular structures.

However, a byproduct of this type of tissue interaction is the production of free radicals. The corneal layers removed by this procedure include the corneal epithelium, basement membrane, Bowman's layer and portions of the corneal stroma. The amount of tissue removed is dependent upon the initial refractive status of the patient and the desired optical result. Upwards of 10% (e.g., a -5.00 D myope) of the cornea may be removed. The surgery is intended to produce a flattened corneal plateau, thus reducing the overall plus refractive power of the cornea and subsequently the amount of minus power required for optical correction. The procedure is targeted primarily at -2.00 D to -7.00 D myopes. To be clinically acceptable, treated corneas should be clear, smooth, predictably contoured, and stable following the procedure. The development of an erodible mask, used in conjunction with the application of the excimer laser, broadens the scope of this procedure, to include both astigmatism and hyperopia. This mask is composed of polymethyl methacrylate (PMMA), which absorbs UVC and is eroded (vaporized) in the process, and a quartz substrate, which transmits UVC without destruction. The surgeon uses these specifically contoured masks to control exactly where and how the laser energy is applied to the cornea, thus allowing selectively contoured corneal surfaces beyond the limitation of an unmasked laser-determined central plateau.

PRK Procedure

Clinically, the procedure can easily be perceived to be oversimplified. The corneal epithelium may or may not be removed prior to the application of the laser energy. After programming the amount of intended refractive change required and baseline ophthalmologic examination data, an algorithm determines the desired excimer treatment parameters. Using helium-neon (HeNe) aiming beams, the patient is directed to look into the aiming device while the surgeon positions the patient's head manually for the procedure. Laser energy is then applied typically over 20-40 seconds, during which time the corneal surface is almost "magically" and irreversibly altered. Postoperatively, the eye is patched for a few days to promote reepithelialization and healing; topical steroids are employed to control postoperative changes. Postoperative care involves management of the reepithelialization process and steroid-dependent factors such as refractive outcome, anterior stromal haze and steroid-induced rises in intraocular pressure. The recent trend is toward reducing steroid use, substituting non-steroidal anti-inflammatories, and for shorter periods of time, approximately 3 months. However, steroids seem more efficacious, minimizing post-PRK inflammation and corneal haze, and playing a role in preventing postoperative regression (1,2,3). Clinically, their use seems unavoidable.

Demographics

U.S. demographic studies (4) predict that by the year 2000, approximately 8 million PRK procedures will have been performed in the U.S. at a rate of 3.5 million per annum. International projections in combination portend of a tremendous pool of applicable PRK candidates who will pursue this procedure enthusiastically.

There is no question that PRK will appeal to most myopes and offers some significant advantages over RK. The most important advantages are the reduction in the risks from intraocular penetration during surgery, less refraction instability, and the retention of near-normal corneal rigidity, severely compromised with RK. The collective international experience (nearly 40 countries) with PRK is 7 years old and involves nearly 70,000 patients, while the U.S. experience is less than 3 years old and involves approximately 3,000 patients. The procedure currently costs approximately $2,000 U.S. per eye and approximately $300,000 U.S. for the excimer laser. However, even pessimistic demographic estimates still encourage medical and commercial development.

Postoperative Results

A review of the literature and data from a current user group symposium reveals that PRK, even early in its technological development, is currently about equal to RK in terms of VA results. Most groups performing PRK report postoperative vision is 20/20 or better in 58-75% of eyes and 20/40 or better in 85-95% of eyes at 1 year. Depending on the preoperative amount of myopia, the percentage of postoperative refractive errors achieved short-term within $\pm$1.00 D of emmetropia (plano) ranges from 70% to 98% in myopes with preoperative refractions less than -3.00 D, from 60% to 92% in myopes between -3.00 and -6.00 D, and from 35% to 44% in myopes between -6.00 and -9.00 D (5,6,7,8,9,10). Even with relatively short periods of follow-up, PRK compares favorably to RK. It can be expected that, as PRK techniques continue to evolve, postoperative results are likely to improve; exactly to what final level, only time will tell. Factors such as the use of erodible masks, new technology, aperture size, control of energy emission profiles, postoperative management, and improved programming algorithms are likely to achieve improved risk/benefit ratios. This outlook presumes no catastrophic issues arise. Until recently, it has been generally recognized that it usually takes approximately 1 year for the refraction to stabilize post-PRK, and this period may even be longer in higher myopes (1,8,11,12,13).

Complications

The main potentially significant issues associated with PRK so far include:

Corneal scarring
Haze/glare/starbursts
Pain
Instability of refraction
Loss of best correctable VA
Recurrent erosions
Over/under correction
Topical steroid complications
Decentration
Corneal islands
UVC exposure

Corneal scarring/haze/glare/starbursts/haloes: Corneal scarring, in the form of corneal haze, is present in virtually all patients postoperatively, fades invariably, and is subject to individualized interpretation and significance. There is no question that the haze occurs and seems to peak in 3-6 months. It is a result of inflammatory and induced histological changes. Analysis of human specimens has been limited, but animal studies and some human specimens have revealed epithelial hyperplasia, increased fibroplastic activity, absence of Bowman's layer, and, following initial obliteration,

reformation of an often discontinuing basement membrane (14, 15,16,17). There has been some evidence of induced Descemet's membrane changes and electron-dense granular material has been seen in primate studies (14) and identified as Type III collagen material, normally not part of the corneal histology (16). These histological changes frost the corneal optical window and are believed to be the source of postop visual haze, glare and starbursts and a factor in causing haloes. Our ability to evaluate the impact of haze and glare objectively and, more specifically, aeromedically is not ideal. In general, all patients will have readily observable corneal haze for 3-6 months postoperatively and most experience significant fading by 1 year (8,9,18). The greater the intended refractive change, the greater and more persistent the corneal haze, which parallels the poorer post-PRK VA results associated with higher myopes. One primate study revealed the histological changes believed to be responsible for corneal haze to persist when the animals were sacrificed at 18 months (16). Corneal clarity postoperatively impacts on several aspects of visual performance, especially at reduced light levels and at night.

Pain: All patients experience pain post-PRK because of removal of the corneal epithelium. This pain generally resolves with reepithelialization of the cornea, which occurs 3-5 days postoperatively. Although corneal pain may have a rate-limiting effect on some individual decisions whether to have the procedure, it is not considered an unmanageable or prolonged problem.

Instability of refraction: By design and from clinical experience, most patients are overcorrected during the first month following PRK and regress over the next 3-6 months. Based on short-term follow-up, it had generally been accepted that the refraction remains unstable for up to 1 year post-operatively, settling within ±1.00 diopter of emmetropia 75-98% of the time. It is associated with 20/20 vision or better in 58-75% and 20/40 or better up to 95% of the time in myopes less than -3.00 D preoperatively (5,6,7,8,9,10). Individuals with higher preoperative refractions have poorer results in general. However, recent observations of late regression beyond 18 months and up to 26 months post-PRK have raised clinical concern that stromal healing may be much slower than had previously been assumed. Persistence of what appears to be the original concentric ablation rings beneath the epithelium has seriously challenged the stromal remodeling hypothesis in post-PRK healing (19). Residual refractive errors occur at least 40% of the time and in most cases would require postoperative correction of some type to achieve best corrected visual acuity (BVA).

Recurrent erosions: Postoperatively, the corneal epithelium must reattach to the underlying corneal stroma. Normal histology involves the reattachment of the epithelium to the underlying basement membrane and Bowman's layer. However, in this procedure, the natural Bowman's layer and basement membrane are deliberately removed; consequently, the corneal epithelium must reestablish anchoring fibers to underlying corneal stroma and reconstituted basement membrane. Basement membrane material is reproduced similar histologically to the original

in most aspects, but differs to some degree. Bowman's layer is not reconstituted, but no one fully understands the importance of this layer to the cornea. Although reepithelialization occurs in all patients within the first postoperative week, the long-term potential for recurrent erosions, especially when these eyes are challenged with contact lenses, remains undetermined. However, most groups have reported that recurrent erosions are not a significant problem short-term. Recent reports of recurrent erosions have emerged and preclude us from totally ignoring this possibility. No post-PRK contact lens studies have yet been reported.

Over/undercorrection: Undercorrection of refractive error can either be an intended surgical target or a result of stromal healing/epithelial hyperplasia. Although most cases are deliberately overcorrected postoperatively, these changes tend to regress over the next 3-6 months. Some investigators have reported changes beyond the 12-month period, so far as late as 26 months, but generally at least 1 year usually has been necessary for stability. Residual undercorrection could potentially be retreated with an additional PRK. However, once corneal tissue is removed and a residual overcorrection exists, correction will require the use of glasses, contacts, or more extensive surgical intervention such as corneal transplantation, or perhaps future laser application. Large overcorrections remain one of the most serious complications and have been reported to occur more often in steroid responders (20).

Long-term topical steroid use: All patients require the use of topical steroids to minimize the corneal haze noted postoperatively and appear to undergo myopic regression if steroids are discontinued too soon (3,21,22,29). However, steroids secondarily delay normal healing, and abrupt cessation of topical steroids has been associated with dense corneal scar formation. To a certain extent, utilization of this medication is dependent upon postoperative response. Some patients may require more prolonged steroid treatment than others. A recent double-blind study supports no statistical significance associated with either anterior stromal haze or refractive outcome after 6 months following PRK, with or without steroids (2), but others dispute this finding (3,21,22). A significant rise in intraocular pressures, associated with long-term steroid use (greater than 3 weeks), has been reported in 11-24% of cases (8). Because of these issues, topical nonsteroidal anti-inflammatory agents are being investigated, but ultimately may not be found as effective in reducing corneal haze as steroids. Clinical experience with respect to this issue continues to evolve.

Decentration: It is important that the photoablated zone be reasonably centered around the visual axis. However, one of the most disastrous consequences is eccentric ablation or decentration in the application of the laser energy. This phenomenon is associated with the most serious postoperative subjective complaints, increased postoperative astigmatism, and the greatest loss of BVA. It has been associated early on with 5% of cases using the erodible masks (20). Although it's rare, when it occurs, it presents a difficult challenge and may ultimately lead to penetrating

keratoplasty (corneal transplant).

Decreased BVA: The potential to permanently reduce BVA postoperatively has been recognized as a problem following PRK. Philosophically, surgeons define success, VA, and scarring differently following PRK. The factors that determine postoperative VA are basically a combination of histological corneal changes, scarring, related optical factors, and a reduction of contrast sensitivity. Regardless, permanent loss of BVA of one or more lines after 2 years has been reported to be as high as 8% of cases in myopes with less than -7.00 D preoperatively and 12-18% in individuals greater than -7.00 D (8,11). It is important to realize that this has been for the duration of follow-up, which has been as much as 2 years in the cited studies. Improvement with time remains a possibility.

Corneal islands: One of the optical requirements of any corneal sculpting procedure is that the resultant refracting surface, in this case the anterior corneal surface and the reepithelialization process, must be smooth and clear. One area of technical evolution in PRK has been directed at controlling how the laser energy is applied to the cornea to smooth the transition from normal cornea to ablated cornea. So far, the histological response to uniform applied energy has had some inherent unpredictability and uncontrollability. In general, the better the transference of the energy and control of its impact on the cornea, the better the post-PRK refractive surface that remains. One issue concerns irregular surface impact of the laser secondary to poor homogeneity in the beam profile. This problem may be exacerbated by other elements such as optical changes in the mirrors or optics of the system and local tissue effects from plasma shielding (23). Second- and third-generation excimer lasers (i.e., the mini-excimer) are being designed to improve upon the laser energy profile and to reduce the potential for surface irregularities from homogeneity of the beam. These factors, in combination with enhanced algorithms, will most certainly improve upon this aspect of the procedure, but it's too early to tell to what extent.

UVC exposure: The excimer uses 193 nm UVC energy. This wavelength possesses sufficient energy levels (6.4 eV) to break biological and chemical bonds, resulting in the formation of free radical byproducts in the surrounding tissue. The mutagenic and carcinogenic potential from this process is difficult to assess. However, the association with the production of free radicals from these types of energy levels and tumorigenesis and cataracts has been established. The human cornea concentrates free radical fighters such as glutathione and vitamin C in the anterior stroma, presumably to counteract this phenomenon from ambient UVA and UVB exposure. Nonetheless, there is a higher association of cataracts with chronic sun exposure. Whether these free radical fighters are sufficient to counteract the effect of the more destructive UVC wavelengths long-term is unknown.

III. AEROMEDICAL ISSUES

The formula for success following this procedure is variable, dependent on both objective and subjective criteria. Surgeons might define success as a function of the final VA achieved

and its complications. Patients, on the other hand, may define the success of this procedure as the ability to exist without the encumbrances of thick glasses. Their new visual status, even though it may be associated with some subjective complaints, may be well tolerated, given the alternative. On the other hand, when we approach surgical procedures aeromedically, these perceived minor annoyances in the general population may be seriously magnified and become considerably more potent and seemingly disproportionate issues when related to aviation. For that reason, it's imperative to approach some of these issues differently, engaging them from the perspective of their impact on aeromedical decision-making.

Glare/haloes/haze/starbursts/dim lighting/night vision difficulties: These issues interrelate and were discussed under general excimer complications. However, we must consider that the target population of this procedure is clearly intended to be individuals in the moderate to high myopic range (-2.00 D to -6.00 D) who preoperatively in most cases would not be qualified for entry into pilot training. One must understand that within this myopic population the overall improvement in VA more often than not would be far more desirable, have a far wider range of acceptance, and generally not be overridden by any secondary glare that might be involved.

Glare testing remains elusive in many respects, and often is subjective or based on patient surveys. Glare is clearly regarded as an unacceptable element in the aeromedical environment. Glare sources within the cockpit environment can be additive and ultimately exacerbated by a compromised final refractive window, the cornea. Present studies reveal that 30-50% of post-PRK corneas generally appear "clear" on a slit lamp examination and are symptomatically regarded as "clear" during the first year, with a gradual tendency toward clearing over time in most cases. Seiler reports glare and haloes in some post-PRK patients despite clear corneas (6). McDonald reported objective corneal haze present in 64% of patients at 1 year (18). One primate study continued to show histological changes that produce glare still present at 18 months (16). There is no question that glare improves postoperatively, but so far, it cannot be stated that it resolves in everyone, either objectively or subjectively.

In one recent study presented at the Summit Excimer Laser User Group Symposium, 51% of PRK patients (myopes preoperatively less than -6.00 D) complained of glare-disturbed night vision 3 months postoperatively, compared to 14% preoperatively; 12% were regarded to have significant problems driving at night (24). At 12 months, 38% complained of minor disturbances of night vision and 5% significant problems. One alarming study assessed post-PRK disturbances in night vision to be present in 78% of its patients early on, 70% at 1 year, and, and 2 years, 10% complained sufficiently enough of glare that they declined to have PRK performed on the other eye (12). The etiology of glare and haloes, besides histo-logical changes, includes a double pupil effect, the sudden contour ridge between normal tissue and ablated tissue, opti-cal effects from paracentral/corneal islands, and an overall reduction in

contrast sensitivity following this procedure. The double pupil effect is a combination of changing pupil size relative to PRK plateau size and optical changes pro-duced by the abrupt vertical edge at the termination of the PRK zone. Under dimly lit or night tasking, these factors combine to produce glare, haloes and starbursts, all of which impact performance (1,25). Gimbel reports patient survey data revealing that 60% of bilateral PRK patients reported reduced quality of vision in dim light, 38% reduced vision in artifical versus daylight, and 50% reported night driving difficulties (28). Data collected on glare and haze has been variably and subjectively influenced by the assessment techniques employed. Many studies report only haze greater than trace. Kim et al. (1) reported subjective night vision symptoms in 21% and glare/haloes in 10% at 1 year post-PRK. McDonald's (18) data has been interpreted clinically by some to have "virtually all clear corneas" at 6 months. However, 89% of those corneas actually were objectively graded to have trace (barely perceptible haze apparent only to trained observers) or 1+ corneal haze (mild haze not affecting refraction). The correlation between corneal clarity and its impact needs to be further refined. Other studies report the levels of glare/haloes at 1 year were greater than trace in 50% of patients following PRK. Within the general population, trace or less glare may be acceptable, given the uncorrected alternative in myopia, but within the aviation community, unnecessary glare can only be a negative factor exacerbated by the other glare sources inherent in that environment.

Reduced contrast sensitivity: Both induced glare and corneal haze would be expected to reduce the overall contrast sensitivity of the eye. VA standards are based on high-contrast Snellen targets. Under lesser contrast conditions, visual function is determined by contrast sensitivity, which becomes a critical element of performance in the multicontrast aviation environment. Although most countries have no current aviation standards with respect to contrast sensitivity, an individual's ability to perceive contrast has been recognized as a critical element in overall visual performance. A procedure with the potential to negatively impact on contrast sensitivity must be carefully evaluated and monitored until suitable scientific work documents its impact.

Sophisticated contrast sensitivity testing post-PRK is lacking. However, using the Vistech contrast sensitivity chart, an overall compromise in contrast sensitivity across all wavelengths which has persisted up to 1 year has been reported in 1 study in 100% of patients post-PRK (25). Although it can be expected that as haze within the cornea recovers, contrast sensitivity performance will also improve, this question has yet to be resolved and remains a potentially significant issue germane to the aeromedical environment, one requiring a determination to be made after longer follow-up. To do so prematurely or to accept ill-defined reduced contrast sensitivity performance in prospective aviators, until it is fully understood, seems to be a compromise in rational aeromedical logic.

Structural integrity/Stability of refraction: There is no question that RK structurally weakens the eye. This weakness occurs by virtue of the fact that nearly 90% through-and-through incisions are made deliberately in the cornea with a surgical knife. PRK removes a thickness of tissue upwards of 10% of the total corneal depth, within a 6-7 mm zone at the corneal apex. Thus, the overall corneal thickness in any individual is reduced by an amount depending upon the intended refractive impact. Although it appears that any structural weakening of the eye induced by PRK, by virtue of the reduction in thickness and the unknown contribution of Bowman's layer to the cornea, would be expected to be much less than in RK, one cannot predict exactly what the corneal rigidity will be post-PRK. Statements regarding corneal rigidity or strength, without definitive studies to support those claims, cannot be made. It is anticipated that this will not be a clinically significant issue and that there is a possibility that the procedure might "weld" the cornea into a stronger structure. The point is, we do not know yet exactly what occurs post-PRK.

There is a hyperopic shift post-PRK and a period of instability that slows over a 3- to 6-month period, continuing at least 1 year and sometimes beyond. Studies have revealed that refractions may continue to be unstable for up to 26 months (19). This was initially thought to be the case with RK, but we have learned that these refractions can remain unstable for periods of 3-5 years, and new data has shown that RK corneas are susceptible to altitudinal-reduced refractive changes. Although the surgical mechanism is different in these two procedures, we cannot predict what the aviation environment's impact will be on post-PRK corneas. This determination awaits further investigation.

Epithelial/subepithelial integrity: We know that the corneal epithelium regenerates and that this tissue normally reattaches to a basement membrane and Bowman's layer of the cornea. PRK, however, removes the normal Bowman's layer and basement membrane over the central cornea, forcing the epithelium to reepithelialize over anterior corneal stroma. At this interface, fine collagen synthesis occurs as well as the formation of new basement membrane material somewhat histologically different from the original. Bowman's layer does not reform. The regenerated epithelial-stromal interface is hyperplastic and associated with increased fibroblastic activity which contributes to this collagen synthesis. The reformation of the basement membrane reveals areas of discontinuity. The presence of Type III collagen has been confirmed in primates by immunofluorescence techniques (26). The long-term sequelae of this new histological alteration of the cornea and the capacity of the epithelium to remain attached to the underlying tissue remains poorly defined. Recurrent erosions or loss of new regenerated corneal epithelium because of ineffective connections with underlying tissue were anticipated to be a more significant problem than has been the case so far. Several recent observations have reasserted concerns over recurrent erosions, but short-term experience is encouraging. Epstein's et al, (19) observations have forced us to redefine corneal stromal remodeling and its time course post-PRK.

Aeromedically, the ability of this altered cornea to support the use of a contact lens has operational significance that will be discussed below.

Endothelial cell layer: The single cuboidal layer of endothelial cells on the innermost surface of the cornea serves as an osmotic pump to remove fluid hydrostatically pushed into the cornea. The endothelial cell population is fixed; these cells lack ability to regenerate. In the presence of increased fluid, the cornea swells and turns opaque; hence, without the endothelium, the cornea would not be able to remain translucent and becomes edematous. Failure of this layer to maintain a clear cornea ultimately leads to the decompensation of the cornea in many disease states causing decreased VA and a potential requirement for corneal transplantation. PRK and its impact on the health of the endothelial cell layers postoperatively, is of concern. So far, there appears to be no recordable loss of endothelial cells, although in some animal studies, there has been a recoverable transient disruption of endothelial cell density over 1 year (27). The production of electron-dense granular material at this layer has been demonstrated in certain animal studies and has raised the question regarding the etiology of this phenomenon and its relationship to PRK (14). There does not seem to be the problem with the endothelium that was anticipated; however, longer-term follow-up in these patients is required to determine the clinical significance of the effects of PRK on this cell layer beyond our limited experience.

Contact lens wear: Because of the aeromedical adoption of contact lenses operationally in some countries for optimal correction of refractive errors (or as an integral part to enhance biological coupling with a weapons system), the post-PRK contact lens issue is a significant one in aircrew. Recognizing that generally 58-75% of the patients are reported to be 20/20 or better uncorrected postoperatively, with 85-95% at 20/40 or better uncorrected, there is still no question that a considerable amount of residual refractive errors will persist and require correction, either by glasses or contact lenses. Even though approximately 75% of the patients are reported so far to have postoperative refractions within $\pm$1.00 D of emmetropia, it appears that 40% of individuals postoperatively will still require correction to assure BVA. In the general population, the importance of this issue is diminished, but aeromedically, it is quite significant. If operationally some countries continue to use contact lenses in aircrew, the health of the corneal epithelium and its capacity to support the use of a contact lens requires serious consideration and evaluation before we assume that aircrew will be able to tolerate these lenses at all following PRK. To date, there is limited clinical experience with soft contact lenses post-PRK. Anecdotally, clinicians involved in PRK studies have found very little requirement to prescribe soft contact lenses in their patients post-PRK. Simply, they are just not being asked for by patients post-PRK. Whether this means the general public is content to have residual uncorrected post-PRK refractive errors because they recognize such a tremendous improvement that any subjective VA disturbance remaining is trivial, or whether glasses suffice, or

neither, remains to be defined before any decision is made with respect to PRK in aircrew who may operationally require contact lenses. Will post-PRK eyes wearing contact lenses be at any increased risk for corneal ulceration or complications because of the alteration in the histological relationship of the cornea post-RK? Will they be able to tolerate contact lenses as long and under the same conditions that have scientifically validated their operational use only after exhaustive clinical research and experience? Additional extensive aeromedical research to justify the use of contact lenses following PRK will be mandatory for those of us who continue to embrace flying candidates with refractive errors, some of whom will certainly pursue PRK privately, or even if at some point we employ PRK for whatever reason aeromedically.

Masking myopic retinopathy: It can be anticipated, just as with orthokeratology and RK in the past, that individuals, in their quest for expensive military aviation training, even in countries with strict entry criteria, will fail to notify the medical screening authorities that they have undergone PRK. In fact, without corneal topography, it will be extremely difficult, if not impossible, to detect individuals who have had this procedure done. These same individuals would have been in the moderate to high myopic category, and not usually within a range of consideration for flying training, even in countries with lenient refractive standards. In general, this range of myopia is at higher risk to develop myopic degenerative retinal changes. It can be anticipated that dilated fundus exams in such cases might not be accomplished according to the otherwise normal routines recommended in such myopes. This could lead to an inability to detect early myopic changes such as tears or holes that might have been identified and treated earlier and puts at risk the considerable financial investment made in what was perceived to be a normal candidate. It would be foolish to assume that everyone who has had this procedure will self-identify during the application process. Corneal topography becomes an essential tool to identify PRK corneas.

Double pupil effect: Seiler reported that more than 10% of patients treated with a 5-mm ablation zone report haloes during night lighting conditions and that glare and haloes also occur in eyes with virtually clear corneas. Even at 2 years, there can be significant glare-induced visual deficits in eyes corrected by more than -6.00 D (6). Although many factors contribute to this night vision problem, the induced double pupil plays a role under dim lighting. By creating a central 6- to 7-mm plateau on the corneal surface, there is the potential to create a situation at the edge of this zone which optically comes into conflict with the dilating pupil under reduced light conditions. This sudden contour cutoff results in optical distortion that will be aggravated by a changing pupillary aperture, creating retinal image degradation, resulting in glare, blurring and visual confusion. Other paracentral corneal effects due to beam heterogeneity (corneal islands) contribute to this phenomenon. Night operations in a high-threat environment make the cockpit a unique environment. This issue is fundamentally different and has significantly

less relevance in the general population, even though within that population we do see problems driving at night (in one study, 10% of the eyes experiencing glare chose not to have PRK on the second eye). No single issue deserves more attention with respect to the aeromedical implications of PRK than the issue of night vision difficulties. Certainly, technological improvements in the future, in both equipment and algorithms, will likely improve on this phenomenon. However, since it is a multidimensional problem, it is anticipated that there will still be considerable potential to compromise night vision. Given that functional clinical tests are less than desirable in assessing this performance category, and given that the nighttime arena will undoubtedly remain supreme, at least initially in any future contingency, then the night vision effects of PRK should loom large in our decision-making process.

Mutagenic/carcinogenic/cataractogenic potential: The same mutagenic/carcinogenic/cataractogenic issues associated with UVC energy levels apply to both civilian and military populations. We cannot begin to predict what the ultimate impact of this radiation will be on the corneal tissue with respect to future scarring and/or the development of metaplastic or neoplastic changes. This is a completely artificial situation, because normally we are not exposed to UVC, even within operational high-altitude environments in or out of the cockpit. We do know that the energy levels associated with the excimer laser are quite high (6.4 eV) and are intended to break chemical and biological bonds within the target tissues to achieve its effect. Unfortunately, it also results in the formation of free radical byproducts--the tissue "bad guys." The association between free radical formation and tumorigenesis is well known. The association of cataracts and UV is also well known. The role of free radical fighters present in the anterior corneal epithelium and their ability to overcome this induced UVC threat is unknown. Will there be an epidemic of cataracts in aircrew 5 or 10 years down the road? Or worse? Are we willing to take this chance in aircrew based on what we know so far? The long-term aftermath and sequelae from this procedure with respect to these issues remains unknown and undoubtedly will do so for decades.

Unknown long-term complications: This issue involves a combination of unpredictable and unforeseeable variables. We do not know what the long-term ramifications of the removal of Bowman's layer to the central cornea will be. We do not know what the long-term consequences of the collagen formation of the type that occurs in response to PRK will be. We do not know if the corneal endothelial cells or any corneal layer will undergo later degenerative changes based on the impact of this procedure. Given the mutagenic/carcinogenic potential of UV radiation in this range, we can only theorize about the long-term consequences of the energy directly applied to the eye. We do not know if UVC, administered in this way, will have any greater impact on cataract formation in the lens. We do not know if any residual corneal haze or scar will worsen in the future, result in changing refractive errors, induced astigmatism or a host of other potentially vision-

debilitating conditions. We do not know what the consequences of all these factors, taken in total, will be on an eye. What we do know is that the 1-year stability issue has been challenged by longer observation.

IV. CONCLUSION

We can all peer into our crystal balls, touch our lucky rabbit's foot, and be optimistically predisposed by the potential significance of this exciting new procedure that makes favorable predictions easy to come by, but we also must recognize that there is a vast difference between acceptability of this procedure in the general population versus the aeromedical community. One can even get up on a soapbox and herald warnings of pending ocular doom. The fact is, none of that is science.

Assessment of PRK and its issues obviously will take many years, and during that time caution should be the byword. Despite the relative inexperience with this procedure and the data presented based on only a few years of observation, there appears to be no question that PRK will provide myopes with an available alternative to glasses and contact lenses. PRK will undoubtedly become routine, proven technology, providing that unacceptable complications do not arise. However, the applicability of PRK to prospective aviation candidates and exquisitely trained assets is an entirely different matter. I can find no medical rationale supporting a procedure's application to a potential aviation candidate pool while it is still clinically evolving and aeromedically unnecessary. It must be remembered that we should approach aviation candidates from the perspective of a long-term investment. They are expensive and important resources who are becoming even more critical as our air forces drawdown. (Hopefully, they will not become an endangered species!) No one can forecast whether an individual who has received a PRK is a good candidate for graduation from flying training, let alone provide a return on the tremendous financial investment made in that individual. What little is known and the vast majority of what is still unknown about this procedure should dictate that medical and fiscal prudence be the rule. I do not believe that, as aerovisual scientists, we should aggressively challenge our standards with a new and unknown area of science, circumventing sound medical judgment, and allow these individuals to fly. If we are interested in selecting the best possible candidates, given the realities of the diminished training allocations, there appears to be no need to consider a procedure and all of its ramifications and potential problems in our specialized population. It makes more profound sense to approach this procedure conservatively from the sidelines, to analyze it with respect to our unique medical environment, and to make an informed but highly specialized decision only after we have satisfied ourselves that the procedure is absolutely safe and, hopefully, predictable. In the meantime, we should advocate for a unanimity of opinion against the appropriateness of this procedure in aircrew. Any endorsement less than this is a Pandora's Box that, once opened, will be difficult to close, on sheer inertia, as vast numbers of individuals receive PRK in the future and challenge our standards. If we do it for one, what stops us

from doing it for all? Until further issues evolve, we should maintain a diligent watch but continue to regard PRK as disqualifying for flying.

PRK truly warrants recognition for its outstanding technological contribution to ophthalmology and many accolades are deserved by those visionaries who developed it. However, I draw the line, at least for the moment, in its applicability to aircrew. Personally, I hope the procedure continues to evolve and becomes the ultimate solution to myopia, because I have a son with -2.00 D of myopia who wants to be a USAF fighter pilot!

I will end with a phrase that appears in some form at the conclusion of many of the studies and papers published on PRK: "The accuracy of a single treatment of PRK is acceptable and stable over a short-term. Longer-term follow-up, however, is needed to assess the stability of the result over multiple years" (30).

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MEDICATION IN THE COURSE OF ACTIVE FLYING DUTY

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SUMMARY

The Czech Institute of Aviation Medicine deals with the practice of medication of airmen without the prohibition of active flying over 25 years. The experience with medical treatment of 420 airmen during the 1982-1993 period is presented in details. Main reason for employment of this policy follows from the successful management of initial stages of primary hypertension as well as of other health disturbances. Hypertension counts for 57,9 % of all cases liable to medication, beeing most often started in the second half of the fifth and first half of the sixth decade. Mean duration of medication took 3,4 years leading to the overall prolongation of active flying for 2,9 years. A combination of two antihypertensive agents, viz. the diuretic and the beta-blocking agent appears to be the most effective method.
Among other frequently applied pharmaceuticals hypolipidaemic and hepatoprotective agents along with vitamin compound remedies should be included. The introduction of medication must precede a thourough medical and psychological examination, repeated prior to waivered certification. Regular observation performed by a flight surgeon or a licenced aeromedical examiner is mandatory. With observance of responsible policy the preservation of an airman in active duty despite his/her medication brings significant economic as well as social benefits without the flight safety impairment.

1 INTRODUCTION

An airman's training belongs to the most expensive activities in preparing a man for professional career. That is why aeromedical authorities make considerable effort to select only those applicants, who provide a guarantee for keeping up their career in active duty for a sufficiently long time. Somewhat different attitude is adopted towards the fully trained and experienced airmen. The process of aging, negative life-style habits and permanent stress accompanying the airman's profession can end the career because of health troubles even in a considerable earlier age, than was originally planned. Despite preventive orientation of aviation medicine the health of some airmen worsene many years prior to the natural leaving of his/her occupation. Most of them have no subjective complaints and keep their motivation for flying at high level. Significant number of those airmen can be relieved of their complaints by application of effective pharmaceuticals. A sophisticated approach of aeromedical specialists can significantly prolong professional longevity of airmen without threatening the flight safety. The problem considering flying with medication has been managed seriously in many countries during the last two decades. Valuable information from research laboratories as well as from aeromedical practice was collected, which currently allows to evaluate this problem rationally.

2 BACKGROUND

The Institute of Aviation Medicine, Prague since its foundation in 1953 provides complete aeromedical health service for all groups of military and civilian flying personnel. Along with ordinary aeromedical examination of all professional and non-professional airmen and air traffic controllers it also provides a thorough examination of all crewmembers, dispatched by flight surgeons or aviation medical examiners with a suspection of serious health disorder. Regularly this examination is performed at the bed ward of the institute for a few days.
When a disease, requiring medication is diagnosed, standard procedure with participation of many aeromedical specia-

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lists takes place under the supervision of Aeromedical Board.The experience obtained in the course of 3 decades in this field is presented.

It should be hardly stated, that nobody should perform in flying or ATC duties while beeing influenced by any drug, which may have an adverse effect on his/her performance, unless Aeromedical Board gives a consent to such an exception (8). All physicians, dealing with aircrew members or ATC staff are usually aware of the potentially negative effects of whatever pharmaceutical they prescribe. In any case they are obliged to inform the flying personnel of all possible side-effects and of the hazard of contingent self-medication.Sometimes problems can arise with medicaments, freely available without medical prescription. In Czech republic ocassionally minor problems arise when a potentially risk medicament is prescribed to an airman by a practitioner,not familiar with aeromedical rules.

First steps in medication of aviation personnel made the Institute of Aviation Medicine, Prague in the early seventies(1). A questionnaire for receiving a basic information on the home-use of medicaments by military pilots was sent to 212 wives. Subsequently a tablet's identification test with a group of 70 pilot and 70 ground-personnel was performed. It followed, that 20 - 41 % of military pilots are prone to the self-medication, mainly in the case of headache or common cold Ordinarily analgesics,mainly with barbiturate component and decongestive remedies were used

In the middle of seventies the hitherto experience with medication of 14 pilots and 3 navigators in the course of previous 7 years was appraised. Five hypertensive pilots were treated with thiazide in combination with dihydralazine-reserpine. Four pilots administered oral hypoglycaemic agents due to a mild form of diabetes. Four pilots were treated with antituberculotics (PAS + INH) and remaining four commercial pilot were treated with anticoagulants, antisclerotic and vasodilatating pharmaceuticals. In no case a deleterious effect of medication on flight safety was noted (2).

Another valuable study was set up by Schamroth et al. in 1977 (3). The results of medical treatment of 96 hypertonic airmen with mean age of 46,5 years were given. Some of them have been controlled up to 10 years. The waiver enabled them to fly for further 249 years. Another group, consisting of 61 aviators, was treated for various diseases, viz. for hyperlipidaemia, hyperuricaemia, glucose tolerance disorders, arrhythmias, hepatopaties and thyropaties. The mean age of referred group was 44 years, medication lasted from 2 to 8 years. Total prolongation of active flying reached 127 years.

Based on similar encouraging communications from the literature (4,5,6) a programme for the regulated practice of medicamentous treatment of aviation personnel without interference in their flight activities was drawn up in the Prague IAM over 12 years ago. Main attention was paid to the staff with hypertension disease, but also other disorders were embodied into the programme.Obligatory regimen was established, based on following rules:

1. The disease without medication would have worsened and in the same way would lead to an indefeasible disqualification.

2. The medication started in the course of temporary grounding in the Institute and its effect was carefully monitored.

3.Potential effect on mental functions was objectively determined by repeated psychological tests.

4.In pilots of single-seat aircrafts a treadmill test, tilt table test and hypoxic test were carried on prior to the final approval of medical fitness.

5. In case of the s.c. risk factors occurence, such as obesity, low physical fitness, smoking, alcohol proneness etc., patient was informed of the necessity to keep the principles of a sound life-style.

6. Airmen, who did not submit to mentioned regulations, were appreciated as unsuitable for flying duties.

In the past 12 years 420 aviation personnel members were followed in the IAM, Prague due to the medication

in the course of active flying. Tables 1. and 2. indicate basic characteristics of the group. Total number of indications is greater than the total of pilots,as some individuals suffered from more diseases. Though the mean duration of medication is by no means long, it can substantially prolong the professional career and in many occasions aloows thy flyer to terminate his/herprofession in regular term.

Mild, borderline or 1st degree hypertension represented nearly half of all indications. Similar results were obtained by King et al. (5). The incidence of hypertension is closely associated with progressing age (7,11 12,13). As Table 3 demonstrates, 57,9 per cent of medicated hypertensive airmen fell between the range of 50 to 60 years.

Table 4. documents in more detail the duration of treatment of 252 hypertonics Maximum airmen were treated from 1 to 5 years, starting at the age 49 to 54 years. Over this margin their number fell gradually, as they approached the end of professional career. In must be stressed, that 33 pilots (13 %) and 49 non-pilots (19 %) flew with waivered certificates for 6 to 11 years!

Table 5. gives an account of the therapeutical strategy. Most often the combination of two remedies was chosen. It minimalized undesirable side effects and at the same time it permitted to suffice with a low dosage scheme, what makes the therapy much safer from the aeromedical point of view.The treatment was always started under the "start low, go on slow" rule. The first choice medicament in most cases was a thiazide in a dose of 25-50 mg. Sometimes an original Czech non-selective beta-blocker metiprazol (Trimepranol) opened the therapy.

In two-combination therapy both mentioned preparations, or a thiazide with calcium channel blocker, or a calcium channel blocker with beta-blocking agent were used. Since late 80ties the non-selective beta-blockers were gradually changed for preparations with selective effect and thiazides were substituted by potassium saving agents, as amilorid (Moduretic, Amiclaran etc.). Nowadays metoprolol (Betaloc), atenolol (Tenormin), bopindolol or pindolol are preferred, together with nifedipin (Cordipine) as the first choice means. Currently isoptin (Verapamil SR 240) seems to be of value as a safe and reliable medicament.

Three-combination therapy has been indicated only in 19 cases, based on combination of diuretics, beta-blockers and calcium antagonists.

Side or adverse effect in the course of the long-lasting medication generally have been rare and mild.In only a few cases calcium antagonists provoked mild crural oedema, without the necessity of interruption of treatment. The affection disappeared in a short time after dose lowering.

Besides hypertension a group of 183 fliers underwent similar procedure due to other diseases. They shared equally between metabolic disorders, hepatopaties and other diseases. Metabolic disorders were represented with hyperlipidaemia and hyperuricaemia. Incidence of these disorders is often associated with an unhealthy way of life. Airmen, whose daily food intake exceeds the sanitary norm, are liable to suffer from mentioned disorders (14). Both disorders were quite common among Czechoslovak airmen after reaching the age of 40-50 years. When a mild elevation of uric acid levels was found out, low-purine diet and alcohol prohibition were prescribed. Only if these simple measures proved ineffective and the serum levels of uric acid permanently exceeded 500 umol/l, treatment with allopurinol was started. Reversion to normal levels was reached in all cases. There was no need to discontinue the drug and no attack of gout was observed as well.

Abnormalities in serum lipides profile were of the same origin, as was the hyperuricaemia. With regard to WHO classification (15) types IIa,IIb and IV have been found. Beside the prescription of dietary regimen, weight reduction and alcohol resctriction,hypolipidaemic drugs were used.

Favourable triglyceride-lowering effect was reached with clofibrate, fenofibrate, bezafibrate and gemfibrosil, as well as with cholesterol lowering drugs cholestyramin and HMG CoA reductase inhibitors (Mevacor). All medicaments were administered in usually recommended doses. Only one case of mildly elevated transaminases (SGPT, SGOT) level for a period of 3 months in the course of Mevacor cure was observed. During the next 6 months their levels returned to normal values, in part due to doses lowering.

8 airmen with 2nd type diabetes were medicated with various peroral hypoglycaemic agents and diet.

Hepatopatics shared with 13,3 % at the medicamentous treatment. Most of them were represented by liver steatosis and steatofibrosis. Mostly they appeared at the age of 35-45 years. Approximatelly in 20 % they were verified by liver biopsy. The disorders were often associated with obesity, hyperlipidaemia and other consequences of going through viral infections. Along with dietary measures hepatoprotective agents, as Essentiale, Aicorat, Legalon and vitamins were prescribed.

The remaining subgroup comprised of 65 individuals. 13 were treated for an enlargement of thyroid gland of different origin and thyroiditis. Except of two all of them were flight attendats. Various combinations of suppressive or substitutive treatment were successfully applied.

A similar number (12) of airmen was treated due to atherosclerosis of peripheral arterial tree in initial stage. Remedies with platelet antiaggregation effect, as acetylosalicylic acid, dipyridamol and xantinol nicotinate were used. The risk factors elimination was a self evident part of the therapy. Patient who refused to stop smoking were eliminated from the "flying-despite-medication" programme.

Four airmen with chronic bronchitis and/or bronchial asthma were medicated with peroral aminophyline and with ketotifen (Zaditen) as a prophylactical means for prevention of bronchial asthma attack.

One pilot was successfully treated with ferric supplementation and vitamins due to post-haemorrhage anaemia. Another pilot with Hodgkin lymphoma in resting state was medicated with hepatoprotective agents and vitamins. One pilot suffering from idiopathic proctocolitis was cured with sulphasalazine in low doses. Allylestrenolum (Turinal) was prescribed to the pilot with prostate hypertrophy. Three airmen were medically treated with non-steroid antirheumatics for osteo-arthrosis. In no case of above mentioned medication any unfavourable side effects or flight safety impairment were observed.

The rest of airmen suffered from various health troubles of transient character, and their medication was governed with various specialists.

3 DISCUSSION

Similarly to the situation in air industry of other countries, even in Czech republic the hypertension represents a serious threat from the point of wiev of airmen s professional longevity. The effort to safe those specialistis in their original working classification lead in past years to the revaluation of earlier strict resistence to their medication in the course of flying. In most cases the medication brings to the affected individual back to the full-value life. At the same time the accessibility of new sophisticated pharmaceutical products with minimum side effects shifts the aeromedical specialists opinion in a more pragmatic and rational direction.

57,9 % of all medicated airmen were handicaped with moderate to mild hypertension. Significant rise of incidence and prevalence of hypertension comes on at the beginning of the 5th decade, i.e. at the top of professional mastery of affected individuals. Cases with secondary hypertension were not included. The medication was always iniciated in hospital (institute) regimen. Each airman underwent a detailed cardiological examination along with special entry psychological investigation. Later on the most suitable me-

dicaments were prescribed. As mentioned above for most cases a combination of two drugs was indicated. Best results were reached with joint application of diuretics and beta-blockers. Undesirable effects of thiazides on glucose tolerance, electrolyte profile or lipid patterns were rare and in every case mild. Psychological investigation revealed type A behavior in most individuals.

Before giving a waiver each medicated individual underwent two additional examinations by a psychologist: one after 3 - 4 weeks of medication and the second after 3 months. All airmen were regularly checked by their flight surgeons or aeromedical examiners every 3 months. If necessary, they were readmitted to the IAM and further examination along with appropriate arrangement of medication was provided observing the described algorithm.

Effective control of hyperetension contributes significantly to the slowing down of organic changes, of the progression of atherosclerotic alterations including its complicacations as well as of the retardation of manifest heart coronary disease. One could speculate upon the possibility of even more successful effect, if the medicated airmen would be more prone to the change of their undesirable life-style habits. In this respects the results are not satisfactory enough.

Despite these difficulties, the contribution of selected approach to the problematic of medication in active flyers must be rated highly both to the operational and to the individual benefits The entire gain in performing of active flying reached 1204 years. No less important is the delay of the development of organic atherosclerotic impairment, particularly of heart coronary arteries, brain as well as kidney arteries. Consistent control over medicated airmen indisputably contributes to the holding of high flight safety level. No one of the flyers with medication participated in any incident or accident, which could be connected with the medicamentous treatment.

4. CONCLUSIONS

1. Medicamentous treatment in the course of active flying while observing strict rules, removing the risk of unfavourable effect on physical and mental functions brings an undoubted benefit both for the aviation industry and for individual airmen, disabled with a curable disease.

2. When carefully managed, pharmaceuticals can contribute to significant prolongation of professional career without threatening the flight safety.

Properly indicated and controlled medication not only does not interfere with demanding airman's performance, but at the same time it reduces the speed of natural progression of system lesions, b accompanying the relevant disease.

4. The participation of airmen in abolishing the s.c . risk factors very often meets with their unconcern.

5. SUGGESTIONS

Looking for more effective means of taking over the medicated airmen for a reasonable care of the health promoting life-style habits could probably lead to still better results.

Elaboration the means of reliable psychological testing of all medicated airmen would further raise the security of the procedure.

6. RECOMMENDATIONS

After appropriate mastering of theoretical resources and of organizational principles by aeromedical authorities it would be advisible to consider the medication of carefully indicated and controlled individuals who obtain the permission to fly with waivered certificates for granted.

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7. ADDENDUM

Table 1. Basic data on medicated airmen

Rank	Total	Percentage
Pilots	306	72,9
Non-pilots	114	27,1
Total	420	100,0

Table 2. Indications for medicamentous treatment

Indications	Total	Mean age	Duration of medication	Total career prolongation
Hypertension	252	49,2	3,6 y	866
Metabolic disorders	60	46,8	2,2 y	124
Hepatopaties	58	42,5	1,8 y	116
Other	65	44,9	2,4 y	158
Total	435	47,4	2,5 y	1264

Table 3. The age at the beginning of atihypertensive therapy

Age period	Pilots	Non-pilots	Total
20 - 29	3	1	4
30 - 34	3		3
35 - 39	16	4	20
40 - 44	13	7	20
45 - 49	46	16	62
50 - 54	74	27	101
55 - 59	31	2	33
60	8	1	9
Total	194	58	252

Table 4. Duration of medication in hypertension

Duration (years)	Pilots	Non-pilots	Total	%
1	63	15	78	31,0
2	37	10	47	18,6
3	20	6	26	10,3
4	23	7	30	11,8
5	20	2	22	8,7
6	7	3	10	3,9
7	6	3	9	3,6
8	9	8	17	6,7
9	4	2	6	2,4
10	3	1	4	1,6
11	2	1	3	1,2

Table 5. Therapy of hypertension in airmen

Therapy	Pilots	Non-pilots	Total
Monotherapy	56	17	73
Two-combination	127	32	159
Three-combination	11	8	19
Four-combination		1	1
Total	194	58	252

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14. Abstract

This symposium addressed a topic of ever-increasing importance — the rationale behind aeromedical decisions. Lack of available data required past decision-makers to be conservative when deciding who should fly and who should not. Papers in this symposium updated available data and provided a focal point for discussion and re-evaluation of aeromedical selection and retention standards. Three discussion periods allowed for open exchange on topics of particular concern to member nations i.e. cardiovascular and neurological problems and HIV. The purpose of this symposium was to exchange data, experience, and management rationales dealing with the very difficult task of aeromedical decision-making. Sharing this information would enable nations to update management protocols based upon experience and data made more powerful by its collective nature. Such exchange would also eliminate costly redundant research and help focus future research and collaborative efforts with the purpose of more effectively using AGARD member nation resources and solving the more difficult or more frequently encountered problems.

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